





# **logging of mountain forests**

**report of the**

**third fao/austria training course on  
mountain forest roads and harvesting  
ossiach and ort, austria, 1-28 june 1981**

**compiled and edited by  
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**ISBN 92-5-101225-3**

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## ABSTRACT

The Third FAO/Austria Training Course on Mountain Forest Roads and Harvesting was held in the Forestry Training Centres of Ossiach and Ort, Austria, from 1 to 28 June, 1981. The Course was made possible by a special contribution from Austria in support of FAO's Regular Programme activities in the field of logging. As with the previous courses, this third was organized by FAO in cooperation with the Government of Austria.

The main objectives of the courses were to familiarize the participants with the problems encountered in the harvesting of mountain forests on a sustained basis, taking into consideration the effects of logging on environment. Particular emphasis was given to the practical planning, surveying, construction and maintenance of forest roads as well as the planning, choice and use of logging technology suitable for mountain forest conditions.

Other important objectives were to draw the attention of the participants to work safety, health, ergonomics and productivity in logging.

The programme of the Training Course included course lectures, country statements, excursions, demonstrations and practical field exercises.

The Training Course was attended by 38 participants from the following 19 countries:

Bangladesh, Bhutan, Burma, Cameroon, Chile, Fiji, Gabon, Indonesia, Jamaica, Malawi, Mexico, Nepal, Nigeria, Pakistan, Panama, Poland, Somalia, Sudan and Tanzania.

Eleven participants were sponsored by Austria, fifteen by FAO, five by the German bilateral aid programme and seven from other sources.

The participants included people from institutions such as ministries of agriculture and forestry, public forestry administrations, public and private forest enterprises and forestry training centres.

This report is the result of the compilation of lecture papers presented. The report is considered to be the most comprehensive one prepared to date since it also contains lectures published in the reports of the previous courses.

With the publication of this report it is hoped that many foresters from developing countries can profit from the information contained herein.

FAO gratefully acknowledges its indebtedness to the Government of Austria for sponsoring this training programme.

#### EDITORIAL NOTE

The papers presented in this report have been edited to the extent considered necessary for the reader's assistance.

The mention of specific companies or of their products or brand names does not imply any endorsement or recommendation on the part of the Food and Agriculture Organisation of the United Nations.

Cover Photo: Mobile tower cable unit in working position, logs arriving at the forest road (Photo: R. Hinteregger).

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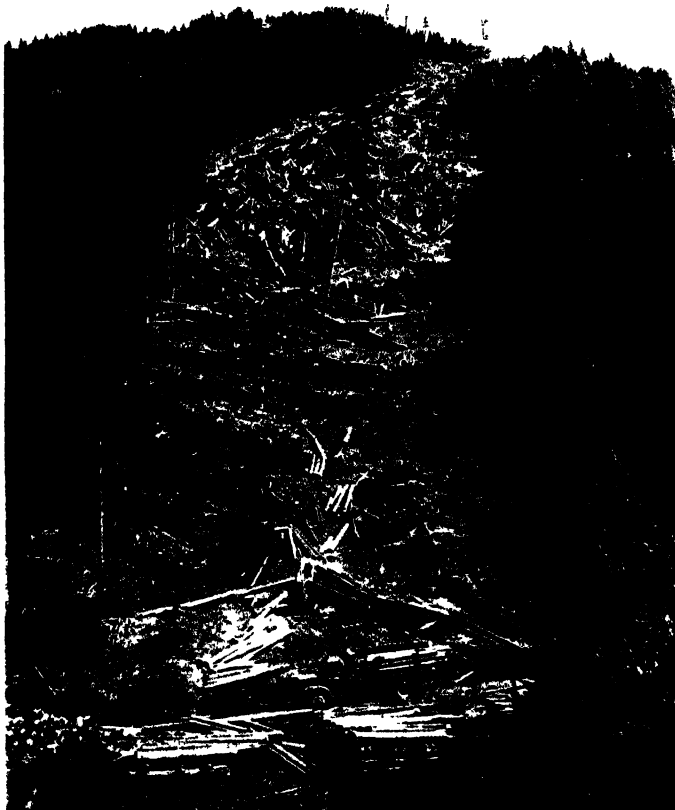
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Strip clearout, downhill log transport by cable crane. Truck being loaded by hydraulic loader (Photo: Federal Forestry Research Institute)



## FOREWORD

### 1. BACKGROUND

In many developing countries, the use of improper wood harvesting methods in steep terrain causes forest destruction which leads to severe erosion and downstream flooding, seriously affecting agricultural cultivation as well as urban areas and their water supply in the plains.

Therefore, great attention and priority should be paid to the preservation of forests which lie in difficult terrain through the application of proper wood harvesting systems, in order to guarantee their protection, social and productive functions in these zones.

Because of the increase in population and expected higher living standards, experts forecast a considerable increase in wood demand for the future, which will necessitate that forest operations be carried out under increasingly more difficult terrain conditions, especially through the opening-up of inaccessible forests by means of forest roads. In many developing countries with high population pressures, forestry in the future will have to be relegated to the less populated areas and to lands unsuitable for other purposes, due to terrain and soil conditions.

In remote areas, forestry can contribute substantially to an improvement of the employment situation for local people through intensive forest management, and therefore contribute to their economic well-being and to the overall development of the country.

In mountainous terrain more labour-intensive extraction methods have to be used than say for forest in easy terrain; this of course increases the employment opportunities available. Additional employment opportunities are gained by forest road construction and maintenance, rehabilitation of devastated land, afforestation and tending as well as stream channel and watershed protection measures. Many developing countries with forests in steep terrain are concerned that proper forest operations are carried out in such a manner as to maintain the protective function of the forests as well as provide a continuous yield; they therefore have a deep interest in resolving associated problems.

The high interest in training activities aimed at addressing the above mentioned problems has been confirmed by the very active response to the participation in the three, already completed, FAO/Austria Training Courses which were held for participants from English speaking developing countries.

Based on the recommendations of the first session of the Committee on Forestry (COFO), which underlined the importance of training related to logging and transport, the Government of Austria generously supported FAO logging training activities by financing the First FAO/Austria Training Course on Forest Roads and Harvesting in Mountainous Forests in June 1975 in Ossiach, Austria.

In line with further recommendations on training and improvements of forest operations made by COFO and the Eighth World Forestry Congress held in Jakarta in October 1978, the series of training courses under a joint FAO/Austria training programme continued. A second Course was held in Austria from 3 June to 2 July 1978. The third Course was held from 1 to 28 June 1981 and a fourth Course is planned for June 1983, again in Austria.

More than 120 participants mostly from developing countries from all over the world have so far participated in the first three training courses. In connection with the training courses, illustrative technical reports were prepared in order that the information supplied during the courses could be made available to a larger forum, especially to foresters from developing countries facing problems in planning, supervising and executing logging activities in mountainous forests. To date some 4 000 copies of the technical

reports of the training courses have been distributed throughout the world, mainly upon requests from individuals, organizations and institutions.

This report is mainly a compilation of the lecture papers presented in this last Course; however, it also includes papers from previous courses and therefore can be considered as a synthesis of the first three courses.

It is hoped that the information contained in this report, as in the previous ones, will again be found useful and serve as a reference book for specific issues in mountain logging.

## 2. ORGANIZATION AND ADMINISTRATION OF THE TRAINING COURSE

The preparatory work and the organization of the Course were carried out in close collaboration between the Forest Logging and Transport Branch of FAO, Rome, the Ministry of Agriculture and Forestry, Vienna, and the Forestry Training Centres at Ossiach and Ort.

The overall coordination was the responsibility of Dr. H. Redl, Head of the International Division and his collaborators. The administration of the Course was carried out by the Verein zur Förderung der forstlichen Forschung in Österreich, headed by Dr. E. Neuberger, assisted by Mr. D. Hanak-Hammerl.

Mr. O. Frauenholz and Mr. A. Trzesniowski from Austria, and R. Heinrich from FAO, Rome, were appointed Course directors. In addition to the Course directors, more than 30 lecturers, speakers and instructors contributed to the Course programme. Lecturers from more than 20 different forestry institutions, organizations and machine and tool manufacturers were brought in to support the forestry teachers and instructors of the Forestry Training Centres at Ossiach and Ort.

Administrative, technical and secretarial assistance was provided by 28 people from the Forestry Training Centres and the Federal Forestry Research Institute.

## 3. PARTICIPANTS

The Training Course was attended by 38 participants from the following 19 countries:

Bangladesh, Bhutan, Burma, Cameroon, Chile, Fiji, Gabon, Indonesia, Jamaica, Malawi, Mexico, Nepal, Nigeria, Pakistan, Panama, Poland, Somalia, Sudan and Tanzania.

Eleven participants were sponsored by Austria, fifteen by FAO, five by the German bilateral aid programme and seven from other sources.

Participants from institutions such as ministries of agriculture and forestry, public forestry administrations, public and private forest enterprises and forestry training centres attended the Training Course.

## 4. PURPOSE OF THE COURSE

The main objective of the Course was to provide foresters from developing countries with basic information on planning and carrying out mountain forest operations with due regard to environmental protection and conservation aspects. Particular emphasis was placed on planning and surveying of forest road networks as well as harvesting systems. Lectures, discussions and demonstrations also covered such issues as safety and health of forest workers, ergonomics and time and work studies, all of which are considered to be important aspects of the harvesting process, in addition to being a means of assisting decision-makers to analyze relationships between man and work, as well as to evaluate work methods and systems and thus productivity and costs.

## 5. RESULTS AND RECOMMENDATIONS

The Training Course was opened by the Secretary of State, Mr. Albin Schober from the Federal Ministry of Agriculture and Forestry, Vienna. Mr. L.R. Letourneau from the FAO Forestry Department, Rome, in his introductory address, welcomed the participants of the Training Course on behalf of the Director-General, Dr. Edouard Saouma, and the Assistant Director-General of the Forestry Department, Dr. M.A. Flores Rodas.

In the first part of the Training Course, which took place in Ossiach, various wood harvesting methods were presented and demonstrated. Participants were required to plan and set up a cable installation as well as assist in the preparation of the planning of wood extraction work. The operation of different ground skidding machines was demonstrated.

During the first part of the Course, besides the classroom teaching, which was kept to a minimum, eleven excursions, demonstrations, and field visits were carried out.

The second part of the Training Course was carried out in Ort and dealt mainly with forest road planning, surveying, construction and environmental factors as well as work organization, safety, health, time and work studies. Again this part was practical-oriented and the programme consisted of some eleven outdoor demonstrations and field exercises.

During the Course participants presented very interesting country statements, introducing brief accounts of forestry in relation to wood harvesting operations.

An evaluation of the Course by the participants highlighted the following:

- This type of practical-oriented training course was of great interest to the participants because it introduced a difficult subject by showing and explaining tangible results which are derived from a long experience in wood harvesting operations in Austria.
- The presentation of country reports by the participants and the subsequent exchange of views on wood harvesting in different countries was considered to be a most valuable exercise for which more time should be allocated in future courses.
- With reference to the subject matter of the Course, the participants felt that instead of making a detailed survey of a cable line and setting up of a cable crane, more time should be devoted to questions of time and work studies and ergonomics. More emphasis should also be placed on cost and productivity studies, comparing various alternatives of wood harvesting systems.
- The participants also suggested that the intermediate technology in logging is very important for most of their countries and that perhaps more time should be devoted to labour intensive methods or a combination of labour intensive and sophisticated methods along with suitable pilot case studies.

## 6. ACKNOWLEDGEMENTS

FAO greatly appreciates and is very much indebted to Austria in assisting FAO's Regular Programme training activities in the field of forest logging and transport by sponsoring and hosting the FAO/Austria Training Courses on Mountain Forest Roads and Wood Harvesting. Special thanks are extended to the Federal Chancellery, Ministry of Agriculture and Forestry, the Directors and the technical and administrative staff of the Forestry Training Centres, as well as the Federal Forestry Research Institute and many other organisations which generously supported the Training Course by either providing lecturers,

supplies, materials, machinery or any other input. In this context we would like to especially mention the forest enterprises and equipment firms who provided their services and assistance, thus enabling the Course directorate to undertake the most interesting and beneficial field excursions and study visits.



Mobile cable unit with hydraulic loader, both mounted on an old truck  
(Photo: R. Hinteregger)

## INTRODUCTORY ADDRESS

by

Leo Reginald Letourneau,  
Forest Industries Division  
FAO Forestry Department

On behalf of the Director-General, Dr. Edouard Sacuma, and the Forestry Department of FAO, I take pleasure in welcoming you to the Third FAO/Austria Training Course on Mountain Forest Roads and Harvesting.

It is an exceptional pleasure to see so many foresters from so many areas of the world, who have taken the time and effort to come to this Course in order to broaden their knowledge on forestry in general, and logging in particular.

At this time, I would like to extend thanks to our Austrian hosts, for without their generous and unstinting assistance this Course would not have been possible. We know from the title of the Course that this is the third of its kind, which in itself attests not only to the generosity of Austria, but also their interest in the subject, in which they are world leaders.

It is only fitting that I mention the close and cordial relations between the Forestry Department of FAO and Austria in this field, especially with Mr. Plattner of the Forest Department and with Dr. Redl of the International Division, for not only through their actions are we able to have such Courses, but we are also able to so rapidly place foresters from developing countries into specialized training courses in Austria.

Now down to the work at hand. You have been selected by your countries to take part in this Training Course so that, upon your return to your home country, you will have a better idea of how to conduct harvesting operations, not only in steep terrain, but to better understand the ramifications of your actions upon the terrain, forests and streams, as well as the social/cultural effects on the people around you - the workers, villagers and industrial users of logs.

I mentioned above that you have been selected. Perhaps some of you applied for the Course out of your keen interest in this field. Logging is a specialized field which is not often taken up as a career by young people from tropical countries. Very often it is looked upon as one phase of a hoped-for long career in forestry or governmental service. No matter what the intention, this Course is designed to enlighten and broaden your outlook. A plus factor will have been won if, in the years to come, many of you are still active in this field.

The logging profession is a difficult one, requiring that one wins his so-called spurs in the jungle. But it is not only an arduous occupation, it is and can be a rewarding one. Rewarding in the sense that one is, through his specialized training, bringing order out of what is sometimes chaos and bridging the gap between the growing of trees and their use.

You will note by looking at the Course programme that, in addition to covering planning, surveying, logging and road construction, time has been allowed for such items as safety, protection, ecology. The programme is broad, but is designed to give you the overall picture of what is required for efficient harvesting of the forests. One of the greatest drawbacks to effective harvesting is the lack of experienced personnel who are capable of making operational decisions designed to ensure control of the harvesters and harvesting operations. The bad effects of this lack of expertise not only show up in higher than necessary production costs, but also often result in lower productivity or even sometimes destruction of the forest, as well as having a negative impact upon the environment.

Proper planning and monitoring are essential ingredients if we are to get low costs, protect the forest and environment and, above all, reap some benefits for the people of our respective countries through the creation of jobs, forest products and the reduction of imports.

Forests, whether natural or man-made, can and usually do play an important role in the economy of your countries and, as such, must be tended with care. Our task as loggers is to create while preserving. In order to do so, we must learn how to apply basic principles and techniques which are generally already known. However, we must also learn to think from those basic principles, for not only might each application require a slightly different technique, but sometimes may require an entirely new concept. In other words, a logger must be adaptable, imaginative and self-reliant.

Please indulge me and let me close with the wish that what you will learn here will be put to good use and that, through this Course, some of you may decide to make logging your life's vocation.



Chainsaw operator wearing safety clothing, making the undercut (Photo: O. Sedlak)

## FOREST RESEARCH IN ALPINE REGIONS

by

Johann Egger  
Forstliche Bundesversuchsanstalt <sup>1/</sup>

### 1. INTRODUCTION

In a distinctly mountainous country like Austria, no feature characterizes the landscape as much as woodlands. Forty-four percent of the country's total surface is covered by forests. Extending over an area of 3.69 million hectares, they produce an annual yield of up to approximately 14 million m<sup>3</sup> of timber. They prevent erosion of the soil, maintain the water balance and protect fertile valleys with their settlements, traffic installations and industries against damage. They offer employment to a large number of people and because of their scenic beauty and high recreational value are a significant factor in the domestic tourist trade.

The forest can perform these multiple economic and social functions in the long run only if its natural life cycle is understood and if its principles are respected in forest management.

The modern Austrian Forest Law of 1975 governs the entire field of forest management as well as all interactions between the forest, the economy and society. This amendment to the original forest law which was over 100 years old, together with forestry research geared to the specific needs of mountainous terrain, provides a sound basis for future forest management.

Of the wide range of forestry research and its findings I should like to present only the most important data in condensed form.

### 2. PRODUCTION

Austria's subdivision into seven growing regions is based on the natural habitats of tree species and, in particular, on the pronounced differences in the climate prevailing in the country.

These subdivisions into growing zones as well as the Forest Seed Law, which provides for stand quality classification aimed at the use of provenance-tested seeds, are the outcome of work carried out at the Forestry Research Institute in Vienna.

In addition to identifying the provenance of seeds, successful afforestation also depends on the quality of the plants used. This is why a continuous effort is being made to improve plant quality through the application of clearly defined quality standards and regular nursery inspections.

Another research project investigates such questions as what growth increment can be expected of the most common tree species in different locations. Forest areas each of about 500 hectares were selected in strictly defined growing regions (such as the flysch zone <sup>2/</sup>, the northern limestone Alps, and so on). After careful site surveying at least 200 000 trees of all age groups are accurately measured. The result we expect from our practical forestry work will be answers to the following questions: Which tree species or which composition of the stand will assure optimum sustained yield in the often very different locations? To

<sup>1/</sup> Federal Forestry Research Institute, Vienna

<sup>2/</sup> A geologic zone in Austria

what extent may the percentage share of individual species be varied, depending on the management objective in each case, without reducing the productive potential of the stand in the long run?

At present our work is focused on surveying high-altitude forests some of which are endangered in our time. The objective of our work is to elaborate silvicultural management guidelines for forest conservation or regeneration, as the case may be.

At the Tulln nursery, comparative studies are being conducted on poplar varieties already grown in Austria; those poplar clones and poplar varieties which tests have shown to be excellent to good are being propagated.

Since 1957 there have been studies focused on progeny testing of isolated spruce groups and spruce stands as well as determining the altitude distribution of mountainous spruce stands. By laying out 44 experimental plots in the different growing zones and at different altitudes we hope to be able to confirm the results of earlier tests on the heritability of the physiological and morphological characteristics of spruce. Provenance tests are carried out to identify the most suitable provenances of Douglas fir.

Studies of water supply in flat and mountainous terrain date back to the earliest days of forestry research. In recent times, the emphasis of this research has shifted to working out a uniform classification system for Austria's forest sites, which is based on soil analyses and phyto-sociological surveys. This uniform classification is aimed at providing a more exact delineation of growing zones in Austria. The growing site surveys conducted under the Austrian Forest Inventory Programme serve the same purpose.

### 3. FOREST PROTECTION

The Institute for Forest Protection acts as an advisory body in all cases where damage has occurred; furthermore, it is responsible for testing pesticides and insecticides used in forestry, and conducts research on new biological preventive and control agents. Today questions of contamination, closely linked to the use of insecticides and fungicides, play a significant role in the institute's activities.

Tests involving the application of Pheroprax, a bark beetle attractant, have resulted in an improvement of recommendations for practical use. Other tests, in which the effect of the toxicologically favourable pyrethroids on the brown pine beetle was studied, have yielded positive results.

The problem of damage from the emission of industrial fumes existed long before the establishment of our research institute. Originally, only air pollution was studied, using air and needle analyses; later, survey maps were prepared and only very recently have so-called false colour films been made, zone by zone, in order to determine rapidly the extent of pollution in afflicted areas. Practical observations of the increment, carried out in cooperation with the Production Research Institute since 1965, have confirmed the earlier studies of smoke damage.

Literature on the protection of forests and pastures against damage caused by game shows that this was already an important issue as early as 1884. It was only after a long interval that in 1956 the question of "forest and game" was once again accorded greater significance. It is the objective of a long-term series of tests to show the influence of game grazing on the vegetation and on forest plants in particular. In addition, topics such as the quantity and distribution of game as well as the extent of damage they cause are being investigated and protective measures tested for their effectiveness.



#### 4. FOREST YIELD SCIENCE

Initially, research on forest yield and management was mainly focused on the current questions of forest mensuration; thus in the period from 1899 to 1908 studies dealing with the shapes and volumes of spruce, larch, white pine and fir were published. Schifffl tried to work out characteristic stem shapes using shape quotients. Equally important were his studies on plant spacing and tending of stocks as factors in spruce raising. In his paper "Growth Principles of Normal Spruce Stands", Schifffl opened up a new path in this field, which was later pursued and perfected by Krenn, Assmann and Frans. Present day yield research is mainly focused on medium-term series of experiments which seek to provide answers to such questions as maintaining constant stem numbers or thinning spruce or pine stands, and which it is hoped will help reduce planting and tending costs. By means of forest fertilization tests the institute performs accurate checks on the economic value of such measures.

The questions of proper plant spacing or optimum thinning methods, so important nowadays, could not have been answered with professional competence if continuous tests had not been carried out in the first years of the institute's existence. The Hauersteig tree spacing experiment (for spruce) carried out by Cieslar in 1892 serves as a model for such experimental work.

#### 5. FOREST ENGINEERING

The first forest engineering studies concentrated on the use of the wedge and subsequently on methods of laying out skidding tracks. After a long interval, these studies were taken up again in 1940 and led to the construction of the Mariabrunn cable unit which was extensively tested in practical operation both as a ground cable extraction unit, as well as a short-distance cable crane. In these field tests the unit primarily served to develop methods of simple cable extraction. It may be considered a model device for its time, which made it possible to design a useful cable winch for forest work.

Subsequently, attention shifted to long-distance cable cranes. Here the objective was to test different novel designs for their suitability in practical work, and in particular, to develop and test appropriate methods of surveying, calculating, setting-up and operating, as well as to devise new skyline supports and anchor types. In close cooperation with the University of Agriculture and Forestry the time, material and money input required for the setting-up and dismantling of cable cranes under different working conditions were determined. The valuable information gained in these studies was integrated into training courses and thus passed on to a great number of foresters.

The worker himself has always been at the centre of all research into working techniques, because the work he is expected to perform must be manageable and physically tolerable in the long run. Ergonomic tests are used to show the physical and psychio strains to which the worker is exposed, and to point to any need for changing the sequence of operations.

In cooperation with the Department of Hygiene of Vienna University, early-summer meningo-encephalitis, a virus disease transmitted by ticks, was analysed. On the basis of these investigations the first map showing the areas in which the disease occurred was prepared, and it was also found that this type of meningo-encephalitis is an occupational disease which afflicts primarily forest workers and forest staff. As a protective measure, an immunizing vaccine was subsequently developed.

As a consequence of mechanization and the increased use of technology, all new machines and devices had to be kept on record, and tested for their suitability in mountainous terrain; also, the most suitable working methods had to be studied. The constant advances in mechanization were closely observed. A great number of studies and analyses of forest work involving the use of the power saw, of articulated wheeled skidders and short-distance mobile tower cable cranes for timber extraction yielded results which were directly applicable

in practice. Standard work norms for chainsaw operations, working hour calculations, lists of existing machinery and devices as well as suggestions for improvements of these machines or work methods are but some examples of these results.

The more highly sophisticated the technology used, the more important and decisive for profitable operations will be the proper organisation and preparation of work. This is the case, for example, in a "broken chain of work" - felling, single-tree extraction by means of a mobile tower cable crane, storage using an articulated grapple skidder, and conversion by means of a mobile processor; or in coniferous timber extraction by helicopter.

## 6. FOREST INVENTORY

The Austrian Forest Inventory developed from the forest stocks investigation of 1952 to 1956. This year it enters its third phase after completion of preceding surveying work done from 1961 to 1970 and 1971 to 1980. The objective of the inventory project is to determine the conditions of and changes in forest stocks by continuous surveys involving the entire surface area of the country. The results of the first ten-year inventory (1961-70) are contained in Information Booklet No. 103. With this detailed information on inventory data, Austrian forestry and management bodies have valuable material at hand for decision-taking in matters of forest policy and forest economy. Preparatory work for the forest inventory started in 1980 is currently under way.

## 7. TORRENT AND AVALANCHE CONTROL

The severe avalanche disasters of 1951 and 1954 prompted the elaboration of an avalanche register for the province of the Tyrol, as well as Fromme's survey which proved that over the past 200 years the alpine timberline has lowered considerably in many regions of the Tyrol and that there exists a close correlation between deforestation and avalanche or torrent hazards.

As we know that two-thirds of all avalanches start below the potential timberline, the avalanche hazard can be combatted not only by technically elaborate structures, but also by long-term afforestation in high-altitude locations. Comprehensive microclimatic, as well as soil and vegetation analyses in addition to studies of the metabolisms of the most important tree species, all have shown that reafforestation at high altitudes is an economically sound concept.

At the Patscherkofel testing station the reactions of various tree species to the environment are examined. Plants are placed in airconditioned wind tunnels where they are exposed to the simulated climatic conditions prevailing at high altitudes. Their reactions are understood from their carbon dioxide exchange. The climatic chamber, which has been in full operation since 1964, has yielded many valuable findings concerning transplantation shock, evaporation shock, the resistance characteristics of young forest plants and their dependence on various external factors.

The Soil Biology Department has succeeded in selecting valuable fungus partners for our forest trees. They are bred in monoculture and used as vaccines to foster the growth and resistance of the vaccinated plants to be used for afforestation. The hitherto unfinished vegetation mapping project for the Tyrol has been continued. Upon completion, this register will consist of 12 maps with a scale of 1 : 100 000. Recently, the project of protective forest revitalisation has also been started. As well as reafforestation in high-altitude locations, revitalisation assumes an ever greater significance.

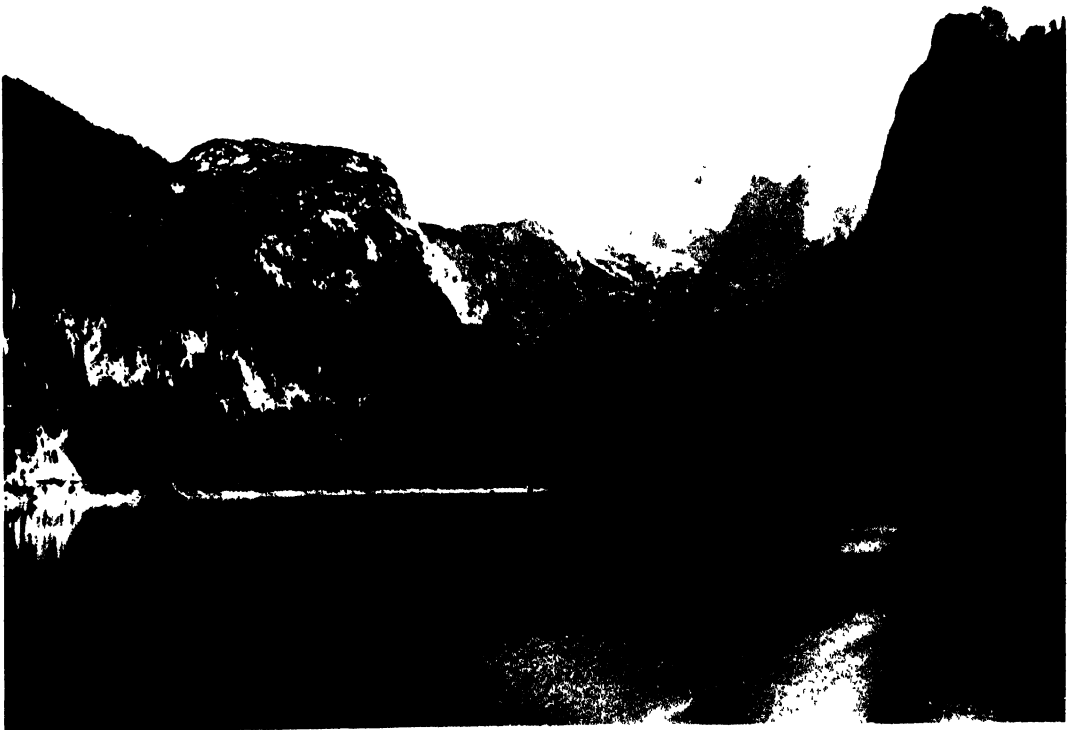
After the major flood and landslide disasters of 1965 the Federal Forestry Research Institute in Vienna established a separate branch for torrent and avalanche research, which is to complement the biological research done in Innsbruck. The Vienna working group is engaged in research into torrent erosion, constructional control of torrents and avalanches.

The problem of torrent erosion is being studied in selected model catchment areas and attempts are being made to prove by hydrographic and morphometric measurements the efficiency of management and construction measures. In the model catchment area of Trattenbach a suitable data-finding method was developed. To date, the following results are available for practical application: suggestions for finding better and more accurate dimensioning data and methods of torrent control construction works, a further development of open check-dams, strain and elasticity tests of steel structures, the publication of avalanche disasters in Austria, and a symposium on torrent check-dams. For a hydrological assessment of different vegetation covers, erosion indices are determined by means of sprinkler tests.

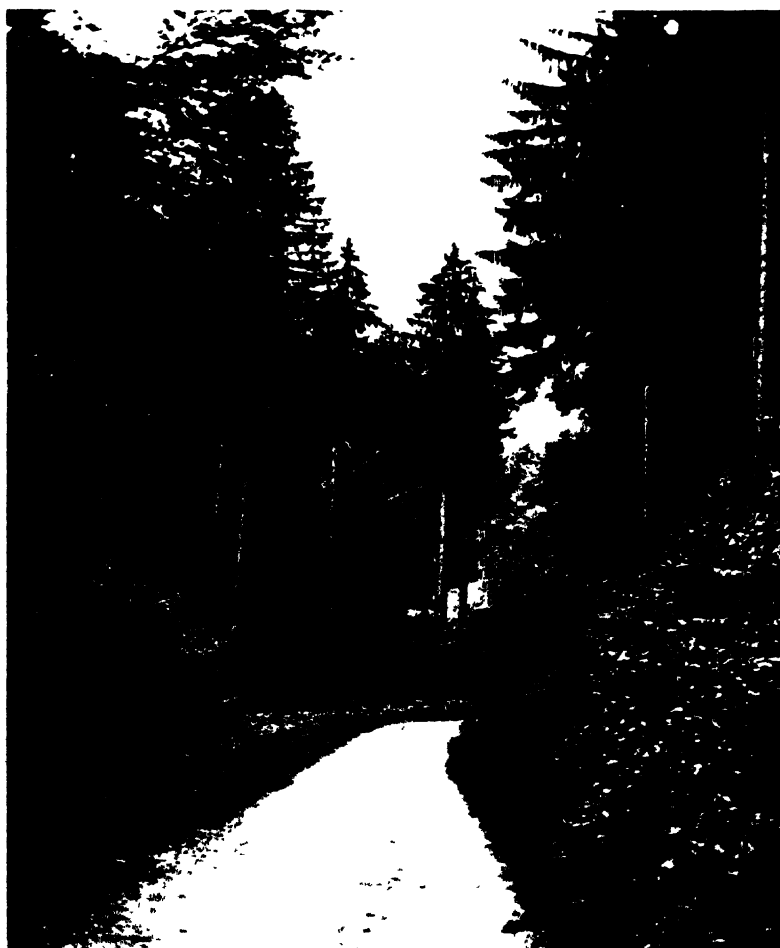
## 8. CONCLUSION

Conserving the forest, and its optimal economic efficiency, as well as ensuring the manifold functions it fulfils for our society, is a major task and obligation incumbent upon politicians and administrators, forest owners and forestry people, and especially on scientists.

Forest research tries to live up to this guiding principle of forestry economy, particularly through the gearing of research projects to practical needs and by purpose-oriented and intensive international cooperation.



Forest research is essential in order to maintain the productive and environmental functions of mountain forests (Photo: R. Heinrich)



A recreation forest with well established forest road (Photo: E. Pestal)

## FORESTRY AND ECOLOGY IN MOUNTAINOUS AREAS

by

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### 1. INTRODUCTION

It is the objective of well-managed forests to guarantee a continuous yield resulting from the various uses of forests. Of these, the production of timber is still the most important. The productivity of a forest depends on various ecological factors and their positive or negative effects. A basic requirement for continuous yield is the assurance of a stable environment, in which all the various ecological functions are maintained. This is true of man-made forests as well as of natural forests which are used for production.

This paper deals with ecological considerations to be taken into account in the opening up by road and harvesting of forests. It will concentrate on ecological factors empirically prevailing in mountainous areas as well as measures that will be needed if these are to be taken into consideration.

It is quite understandable that a compromise between economic and ecological intentions has to be sought. It would be wrong to plan forestry measures only on the basis of currently available economic facts and figures. Major natural disasters in Central Europe were the outcome of such a misconception.

### 2. FORESTS AND WATER

In Central Europe - and in almost all mountainous areas of the world - precipitation increases with altitude. Apart from the fact that dry periods occur in certain seasons of the year and that some areas may have no rainfall at all, it is still generally true that water is abundant in mountainous regions. As experience has shown, an over-abundant supply of water - in particular the type of precipitation which occurs suddenly - is the main ecological problem in mountainous areas.

Since slope gradients are steep in mountainous areas, especially in geologically younger formations, the hydrological problem is inseparably connected with the erosion problem.

Studies carried out decades ago in various parts of the world have clearly shown that of all the different types of vegetation it is the forest that can prevent major disasters and guarantee the conservation of landscape and soil. Other points to be raised in favour of the preservation of mountainous forests are the good future prospects for selling timber and improvement in the technology of wood harvesting, in particular of extraction methods.

### 3. SOME EXAMPLES OF STUDY RESULTS

#### 3.1 Surface run-off

Precipitation run-off is compared for two neighbouring valleys with different degrees of forest density.

<sup>1/</sup> Federal Ministry of Agriculture and Forestry, Vienna

Valley	Forest density %	Precipitation mm	Run-off l/ha/sec.
Sperbelgraben	95	35	8.4
Rappengraben	35	35	above 33

(Study carried out by Engler, 1900, Switzerland)

After heavy rainfall the flood peak in forest-covered terrain was reached only after 36 minutes. In clear-cut terrain it was registered after 15 minutes and it was 2.5 times higher. (Study carried out by Hibbert).

Still higher run-off figures were found on ski slopes in clear-cut terrain (comparable to pastures, compacted soil): the run-off was six times higher than in forests; rain infiltration into the soil was 30 cm, whereas into forest-covered soil it was 110 cm. (Study carried out by Stauder, Austria).

Decrease of runoff with increasing stand density:

Example of a pine stand

<u>Degree of stock density</u>	<u>Run-off in %</u>
0.2	25
0.6	9
0.8	2

### 3.2 Erosion

A soil layer of 18 cm in mixed deciduous forest is theoretically eroded after 575 000 years, in meadows and pastures after 82 000 years.

If the same soil layer carries no vegetation at all, under the same conditions, erosion takes only 18 years. (Study carried out by H. Walter).

Avoiding erosion by a low cover

Degree of area covered in %	Precipitation (thunderstorm) in mm	Run-off in %	Soil erosion kg/ha
75	60	2	100
10	60	73	10 000

(Study carried out by Susmel)

Erosion rates before and after road construction.

Annual precipitation: 1 500 mm.

Erosion rate of soil/ha/year before opening up	20 - 30 kg
During construction (newly excavated roadbed)	2 000 - 4 000 kg
After termination of works and revegetation of the batters	100 - 150 kg

(Quoted from Pestal, studies carried out in the USA)

### 3.3 Avalanches

Snow is irregularly stored in the forest; dangerous stratification is avoided. Trees have the effect of poles which support the snow cover. An irregular high-density forest in which the stand structure is stratified gives the best protection.

### 4. MOUNTAIN FORESTRY BASED ON ECOLOGICAL CRITERIA

Study results have shown that, particularly in mountainous areas, forestry has to be adjusted to ecological requirements. In order to preserve the environment forest economists have to try to avoid the following hazards:

- major surface runoff
- erosion
- avalanches in forest-covered areas.

Whereas floods and avalanches cause mostly temporary damage, even if it can be repaired only after decades, erosion causes permanent and irreparable damage to soil in almost all cases. Unfortunately, it is still not widely known that the top layers, i.e. the humus layer and the humus- and mineral-containing soil layers (often only a few centimeters in depth) are responsible for the supply of nutrients. Mass timber production depends for the most part on these top layers. It can be seen from this fact that erosion is not only an ecological problem; it is also an economic one. Central European foresters prefer mechanisation to be adjusted to silvicultural rather than other needs.

Ecological considerations will always affect economic decisions. Measures which take ecology into account should not be directed at maximising short-term profits but should be based on the long-term uses of forests.

I do not want to give the impression, however, that in Europe the profit-earnings ratio is so favourable that rationalisation and mechanisation can be sacrificed for the sake of fulfilling sophisticated ecological demands. Quite the contrary is true: high labour costs and a shortage of labour on the one hand, and only a slight rise in timber prices on the other are a permanent challenge for forest economists to find new ways to harmonise economics and ecology. Let me illustrate my arguments with some figures.

### 5. DATA FROM AUSTRIAN FORESTRY

Of all Central European countries, Austria has the highest percentage of woodlands: 44 percent (compared with Czechoslovakia 35 percent; France 24 percent; Fed. Rep. of Germany 30 percent; Italy 21 percent; Switzerland 24 percent; and Yugoslavia 30 percent). This corresponds roughly to 3.7 million ha, of which about 3.2 million ha are productive forest areas.

Austria's forests are situated mainly in mountainous terrain.

Altitude above sea level in m	Productive forest area in %
Up to 900	51
From 901 to 1 200	22
From 1 201 to 1 800	27

Slope gradients in forest areas

Slope gradient In degree	In percentage	Productive forest area in %
0 - 20	0 - 36	49
21 to above 40	+ 84	51

In 1976 roundwood production accounted for roughly 10 million m<sup>3</sup> from an area of 30 000 ha. Of this, 18 200 ha were clear-cuttings and on 12 500 ha selective felling was carried out. The average harvested wood volume of final cuts was 324 m<sup>3</sup> per ha, representing a standing volume of 400 m<sup>3</sup> per ha. In 1976 the area reforested amounted to 17 700 ha.

Earnings - cost ratio

- The hourly wage of forest workers increased by almost 100 percent between 1970 and 1976.
- The price of roundwood to be used as sawn timber (spruce, fir) increased by some 20 percent in the same period.

Cost components 1975 (large forests) in % of earnings		Types of costs 1975 (large forests) in % of earnings	
Timber harvesting	43	Wages	39
Silviculture	8	Salaries	19
Skidding equipment	10	Material	7
Administration	33	Outside labour	16
Buildings	6	Business tax	5
		Depreciation	9
		Others	5

} 58

- Earnings per ha of productive forest area obtained from final cutting and thinning in 1975: A.S. 2 743 (US\$182)
- Costs for reforestation per ha including tending and weeding were roughly A.S. 15 000 (US\$1 000)

A.S. = Austrian Schilling



- Examples of average productivity in power sawing (Austrian Federal Forest Enterprise)

	Wood volume in m <sup>3</sup> felled per working hour		Increase in %
	1970	1976	
Final cutting	0.59	0.88	50
Thinnings	0.35	0.57	63

## 6. BASIC ECOLOGICAL PRINCIPLES

The above data, the prevailing situation and experience from this situation point out the need for ecological principles to be applied to forestry. In view of the general topic of this Course, I will concentrate on the opening up of forests and timber extraction.

### 6.1 Opening up of forests

Road construction is the first silvicultural activity of environmentally-conscious forestry in mountainous areas.

Careful planning. Any opening-up project requires far-sighted decisions that will determine the development of the area over a long time. Planning errors will become obvious and frequently cannot be corrected later.

Integrated planning. Timber transport accounts for only 30 percent, or less, of forest road use. In most cases the roads serve multiple purposes in intensive forest management (reforestation, tending, forest protection, among others) and also in social services (transport of workers, transport in case of accidents, and so on).

Clearing plans. The first opening-up of virgin forest includes the clearing of the forest and its conversion into arable land. This clearing, in particular the distribution of forest land, must be given special attention because of the erosion hazard. In mountainous areas the percentage of woodlands should be kept high.

If there is a potential hazard of avalanches in winter a wide forest belt on the valley slopes should be maintained.

Degree of opening up. Empirical data have shown that with the present degree of mechanization the optimum density of roads in Central European forests can be reached only at 30-40 m per ha of productive forest area. Only this high roadnet density makes cutting feasible on a small area.

Extraction alternatives. The road network will always be the backbone of an opening up project. In steep or rocky terrain or on soils with low bearing capacities, road construction may have disastrous consequences. In these cases, alternatives have to be considered (e.g. use of temporary cable installations, etc.).

Careful construction. Storage of large masses on steep or rocky terrain should be avoided. Roads and skidding trails should be designed to suit the terrain. Gradients have to be kept low. Drainage of the road surface must be sufficient. Natural or artificial revegetation of the batters is essential, particularly in rocky terrain.

Only consistent control of construction works will guarantee efficiency and good results.

## 6.2 Timber harvesting

At present and in the future, forestry work which is based on ecological principles will not be possible without using large-size machinery. Big machines are profitable, however, only if they are used on a large scale. This is unfavourable from an ecological point of view in steep terrain. Heavy machinery is usually not employed in mountainous areas.

Harvesting has to be carefully planned. Various harvesting and skidding methods have to be compared. The method involving the least costs need not necessarily be the cheapest. Higher costs are justified if damage can be substantially reduced. Logging in steep terrain and close to the timber line of high altitudes must be carried out cautiously.

Small clear-cuttings. Large size clear-cuttings are no longer carried out in Austria. Well-spaced small clear-cuttings (strip to very narrow strip cuttings) help to prevent major erosion.

Harvesting methods. Methods in which leaves, needles, branches and stumps remain on the felling site are preferable. Whole-tree logging leads to a reduction of the nutritive substance in poor soils. Even equivalent mineral fertilization cannot completely compensate the loss of nutritive substances. Branches and stumps are important to counteract erosion in steep and mountainous terrain.

Skidding. Machines which cut furrows into the soil are not advisable because they result in soil compaction and erosion. Gravity skidding is not advantageous over long distances. An alternative would be uphill winch skidding.

Skidding in selective fellings. Trees should fall in a fishbone pattern with the skidding corridor as their centre line. Damage to trunk and roots of remaining trees has to be avoided by support measures: cushioning with branches; use of chutes, etc.

Torrent beds. Extracted timber must be quickly removed from torrent beds and stored at a site which is safe from floods.

Felling sites must be reforested right away (soil must be covered quickly) with plants that are compatible with the stand. Seedlings should be taken from the same altitude as the area to be afforested.

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FOREST ROAD CONSTRUCTION  
BETWEEN ECONOMICS AND PROTECTION OF NATURE

by

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1. INTRODUCTION

Never have so many roads been built world-wide within such a short span of time as today. Sturdy earth moving machinery and rational drilling and blasting techniques make forest road construction profitable in areas which only a few decades ago were not considered suitable terrain.

We have every reason to take advantage of modern technology because the situation of the world economy has never been more favourable for the opening-up of forests, nor will it be more so in the future with energy prices constantly rising. As construction costs depend heavily on energy prices, we cannot be sure that 20 or 30 years from now we will be able to construct the forest road we do not build today. Should the prices of diesel oil and blasting materials rise more rapidly than timber prices, the construction of forest roads will become increasingly costly.

High mountains, deep valleys. Where there is light there will be shadows. Thus it was inevitable that the intensive construction effort of the past decades should give rise to undesirable side-effects. Fortunately we know today how we can reduce these to a tolerable level.

From this it follows that our current discussion on forest road construction centres on two controversial points: profitability versus environmental protection. It is our objective to reach a compromise in each individual case that will be satisfactory to both points.

2. ECONOMIC CONSIDERATIONS

Here we are not concerned with the silvicultural or management aspects of forest roads, but with the economics of construction.

2.1 Savings through routing appropriate to the topography

A road construction method is economic if the sum of construction and maintenance costs is kept to the lowest possible level. The first and most important decision affecting the cost level is the selection of the route. When 2 000 years ago the Romans built their roads, they used a geometric routing system, because they had soldiers in their standing army who also had to be kept busy in times of peace. Today there is no justification for designing a forest road which would consist of circular bends connected by tangential lines. This method would not only harm the natural topography but also push up construction costs quite unnecessarily - particularly in narrow valleys and on steep slopes. Neither straight lines nor circular bends are found in nature, and contour lines always resemble free curves (which are, however, frequently similar to three-centred bends).

The more closely the route follows the contour lines, the less the damage will be to the statics of the hill structure and watercourses, and the more perfectly the forest road will blend with the surrounding landscape. Fitting the route to the terrain is, of course, no longer possible if this means not attaining the minimum radius. However, this can easily be avoided by checking the radius of bends during construction, using a measuring tape.

In the training forest of Vienna University the road network covers more than 50 km, but with the exception of the manually constructed road section dating back to 1938/39, not a single road forms a truly circular bend. Three-centred bends are sometimes accused of presenting a danger to motor traffic because the initially large radius is reduced within a short distance, and then again becomes increasingly larger in the exit section. This is, however, not dangerous, but rather an advantage because in this way the driver is forced to keep to a speed of 30-40 km/hour. If he exceeds this speed, he risks not making the bend. And, let us be honest, who will observe a speed limit unless he is forced to do so? A speed limit is the most important precondition for lowering road maintenance costs.

It may also be pointed out that hikers in forests normally dislike geometrically designed routes and prefer forest roads which, like hiking trails, cling to the slopes and follow the terrain naturally.

## 2.2 Cost-saving construction of earth routes

In the revolutionary early days of mechanical forest road construction, builders were happy when favourable soil and weather conditions permitted an efficient angledozer driver to complete 300 metres of rough subgrade in a day. If necessary, a thin layer of crushed stone was subsequently applied; thus the cost for one linear metre of forest road with a subgrade 5 m wide and capable of carrying trucks normally amounted to as little as A.S. 100-150. However, the subsequent maintenance costs were often exorbitant. Therefore, mechanical earthworks are now oriented to incurring the lowest possible maintenance costs.

Now the angledozer driver is required to make as much of the subgrade as possible on the subsoil. The earlier practice of removing relatively thick layers first and then shoving the loose earth material about in order to level the inevitable "washboarding", called for additional crushed-stone material. Today the caterpillar driver starts at the upper edge of the hillside slope, removing increasingly thinner layers as he progresses toward the subgrade. Here the use of two caterpillars is of advantage. The rough subgrade is made by the larger caterpillar which also removes stumps; the smaller machine is subsequently employed for fine grading.

### 2.2.1 Step outs

The aforementioned method cannot prevent an intermingling of humus topsoil and mineral subsoil; thus the fill cannot be kept clear of roots and branches. As a consequence, subsidences will gradually develop, necessitating further grading, crushed-stone application and rolling. The best method for keeping the humus subsoil, stumps and roots clear of the load-carrying substructure is the step type of cut.

In this procedure the caterpillar starts at a level of about half a metre below the future subgrade, moving the out material, which is intermingled with humus soil and roots downhill. In a second operation the machine starts at about half a metre above the future subgrade and moves the loose material down to the surface first created.

In a third operation, the caterpillar shoves this material down on to the lower portion of the hill where, with its roots and branches, it forms an entanglement which catches the material rolling downhill. In the fourth and last operation, the rough subgrade is finished on almost pure mineral soil. This method increases the costs for earthworks by roughly 50 percent, but the additional money input is offset by savings in crushed-stone application and road maintenance.

Whereas in the past angledozers were predominantly used for earthworks, today a shift has occurred toward traxocavators. These not only remove the out material laterally, but can also transport it longitudinally over distances of up to about 50 metres. Thus they cause less damage to the terrain and in particular to lower slopes, which compensates for the higher costs of earthworks.

### 2.3 Cost-saving rock drilling

With increasingly sophisticated construction methods, rock drilling is assuming ever greater significance. In this field a technology has been developed which has reduced costs for forest road construction in rocky terrain in many instances below construction costs in loamy zones. What is the use of a cheap rough subgrade in a flysh <sup>1/</sup> terrain if a crushed-rock layer of 40 cm thickness must be applied afterwards? On rocky ground, roads can be built in any weather, even in winter. Normally only a thin layer of crushed rock is applied, and in some cases none at all is required, and maintenance costs are at an absolute minimum.

The cheapest method of constructing roads in rocky terrain is deep-hole drilling parallel to the axis of the road. As the drill hole is 10-15 m long, a route of up to 60 m can be blasted from the rock in a day, using two workers and two machines. Blasting debris may, however, be accumulated on the lower batter which will arouse protests from both nature conservationists and forest hikers.

This method of rock drilling can be applied in this form only in areas where blasting debris does not bother the owner of the forest and is not visible to the public.

#### 2.3.1 Portional blasting

Last year a significant improvement was made to the method described above. As usual, first a hole 10-15 m long with a diameter of about 80 mm is drilled into the rock. After the dynamite fuse has been attached, the front charge is placed at the bottom of the hole. The next charge, which normally consists of a third or quarter cartridge of gelatine donarite 1, calibre 60 x 700, is placed in the drill hole at a distance of 1 to 2.5 m, thus leaving a space which is not filled with detonating agents. Only the mouth of the drill hole is carefully closed and tamped.

When the charge is fired, the entire charge column is uniformly filled with highly compressed explosive gas. When the pressure exceeds the critical limit, the first charge of the explosive is detonated over the entire depth of the drill hole, but the debris is not thrown very far; the rapid pressure surge upon firing is followed by an equally rapid pressure drop as the rock material yields, so that the explosive force is not very strong. In the best case the debris remains on the subgrade almost in the same fashion as a fill layer.

This procedure, described as "blasting with extended charge and intermediate cavities", is also used in mining where a mild explosive effect is similarly advantageous.

Portional blasting cannot be used if the volume of the material to be blasted is very large and if the drill hole has to be fully charged. This procedure is also not applied when the rock material varies in thickness or strength, because in this case the explosive "shot" could blow out the weakest point.

This goes to show that in many cases safe rock blasting can only be ensured by employing the head drilling and millisecond firing method. This practice results in minimum damage and in smaller debris fragments which do not roll very far.

<sup>1/</sup> This is a specific geologic formation in Austria.

We no longer use compressors and hand-operated hammer drills, but excavator-mounted hydraulic hammer drills. In Austria, in an effort to humanize work, we no longer allow operators to hand-hold their drills for weeks or months on end, as this often results in damage to intervertebral discs or joints.

## 2.4 Excavator work

For two decades it was believed that working with an excavator would multiply construction costs by five to ten times the normal cost per linear metre of forest road. Now it has been shown that it was not the excavator that sent prices up, but rather the common practice of using a truck for transporting the excavated material along the road. It is quite obvious that having several trucks waiting in line as well as the grader which had to be used at the dump site meant a disproportionately high increase in construction costs.

Recently a new method has been introduced: the work of the excavator is no longer combined with transporting material along the roadbed, so excavators can be profitably used for construction in earth and rock. At first graders were still needed because it was impossible for an excavator to make a plane subgrade - but only two years ago a driver succeeded in making an acceptable subgrade with an excavator, working perpendicularly to and along the roadbed axis. Meanwhile excavators are being increasingly used to make rough subgrades. As a consequence, it is now possible to construct forest roads at acceptable costs and with minimum damage to forests even on very steep slopes with gradients of up to 80 percent. In such cases the excavator piles up the blasting debris on the lower batter to form a block type of wall, thus reducing to a minimum damage caused by rolling material and heaps of debris.

## 3. ENVIRONMENTAL PROTECTION

The stone which I have placed here on the table put in its artificial resin setting, is one of the Via Egnatia which is the oldest known cross-country road with a stone setting. King Philip, the father of Alexander the Great, had this road built as a link between Thessalonik and Neapolis, today's Kavala. Alexander's armies marched on this road to the East where they established an empire which extended from the Nile to Indus. Fifteen hundred years later the Turkish armies marched to the West and conquered an empire which outlasted Alexander's.

As these examples show, road construction permits the movement of people and goods. As soon as a road is completed, its constructor has no control over anything that travels along it in either direction. Moreover, roads normally have an unlimited life.

As long as Professor Sklavounos lectured on forest engineering at the University of Thessaly he banned all road construction in the training forest, arguing that "forests must not be opened up - or they will disappear". This was the lesson learnt from 4 000 years of Greek history which demonstrated that forests survived only in absolutely inaccessible terrain.

In view of this experience, I should like to appeal to you to check in each individual case before a forest road is built, whether the forest can afterwards be adequately protected against overcutting and indeed destruction. Legislation alone will not suffice. Often common practice and distress prompt people to ignore interdictions, thus causing irreversible damage.

Throughout the world, but particularly in tropical rain forests, we see alarming examples of extensive forest devastation which was preceded by the construction of a road. Of course, it is not often a forest road but a public road which has led to such devastation, but its effects are the same.

As early as thousands of years ago man turned spacious woodlands into deserts, as in the Mediterranean region or in China, for example. Today man has multiplied his strength by employing machines; unfortunately, these are not always used to advantage. It is our task to diagnose a situation in time; as long as a development project presents a hazard to the existence of a forest, the Greek professor's view is justified.

THE FOREST ROAD INVENTORY PROJECT AND ITS EFFECT  
ON FINANCING AND PLANNING MEASURES

by

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This paper tries to describe the Austrian situation and our ways of building forest roads and you may regard it as a stimulus to finding out the best solutions to similar problems.

Austria is a country with private as well as state-owned forests, which are distributed among 250 000 owners. The major part, about 54 percent, own up to 200 ha, 30 percent own more than 200 ha and 16 percent of the forests are state-owned. These figures are taken from the forest inventory report 1961-70. The data relate to a forest area of 3 705 469 ha.

The exigencies of the post-war period and a certain personnel shortage induced owners and the various authorities to open up the available forest land. A decisive factor in all these projects was the need for timber as a raw material for construction and industry. With the help of the first inventory results, papers were prepared describing the degree of opening up of Austria's forest land. They were then used as a basis for further development.

This collection of basic data, the theoretic background which was the work of the French scientist Buffon, was started in 1966, and is still being worked upon. Calculations of road length and roadnet density are based on the number of junctions and the influence a certain forest section exerts on the road.

The working guidelines for the surveying staff contained the following criteria:

- determination of altitude given in steps of 300 m each;
- specification according to public tracks or roads;
  - cooperative, transport and forest roads with private or public right of use;
  - private tracks or roads owned by individual forest owners;
- determination of road width:

2 - 3 m	roads or tracks for lorries or timber
3 - 5 m	transport vehicles
5 m and more	
- determination of road surface:

not reinforced
reinforced base (gravel, compacted and stabilized)
reinforced base and special surface (macadamised, concrete covered).

The road length data are taken from the last evaluation of the forest inventory results (period from 1971 to 1975). The data for area, supply and production are taken from the inventory of 1961-70.

The following results were obtained by the survey:

### Roads accessible by lorry

The following were the data for road length and road-net density in fully productive high forests and protective forests in production:

<u>Forest specification</u>	<u>Road length</u>		<u>Road-net density</u>
	<u>Km</u>	<u>%</u>	<u>linear m/ha</u>
Fully productive high forest	91 410	96.6	33.3
Protective forest in production	3 237	3.4	8.6
Total: high forest in production	94 647	100.0	30.3

It will be seen that density for roads accessible by lorry in fully productive high forests is almost four times as high as in protective forests in production. The road length figure for protective forests in production given as a percentage of the area is only 3.4 percent while it is 21.1 percent of the area of high forests in production.

### 1. TYPES OF OWNERSHIP

For the various types of ownership the following figures are given by the forest inventory for fully productive high forests:

<u>Types of ownership</u>	<u>Road length</u>		<u>Road-net density</u>
	<u>Km</u>	<u>%</u>	<u>linear m/ha</u>
Small forests	61 682	67.5	37.1
Forest enterprises	22 273	24.4	29.7
State forests	7 454	8.1	22.3

Forest enterprises and state forests have a considerably smaller road-net density, which can be explained by the fact that roads in big forests are mainly for opening-up. In smaller forests the public road-net and agricultural transport roads contribute to a higher figure of road net density. The definition of the fully productive high forests as given by the forest inventory differs slightly from the one applied by the Austrian State Forest Enterprise.

In protective forests in production the small densities of 7.0 to 9.5 linear m/ha are sufficient.

### 2. ALTITUDES

<u>Altitude</u> <u>above sea level</u>	<u>Fully productive high forest</u>		<u>Road length</u>		<u>Road-net density</u>
	<u>Size of forest</u>	<u>area, ha</u>	<u>Km</u>	<u>%</u>	<u>linear m/ha</u>
Up to 900 m	1 549 864		57 525	62.9	37.1
Up to 1200 m	608 758		20 788	22.8	34.1
Above 1200 m	589 480		13 097	14.3	22.2



The road-net density in fully productive high forest decreases considerably with rising altitude. Road-net density at altitudes up to 1 200 above sea level is 91.9 percent of the density figure for the lowest level; at altitudes above 1 200 m it is only 59.8% of the density figure at the lowest step.

In the following, the distribution of forest area and percentages of total supply and cuttings as given by the stock inventory are compared with the distribution of road length figures at the three levels of altitude.

<u>Altitude above sea level</u>	<u>Forest area %</u>	<u>Total supply %</u>	<u>Cuttings P.a. %</u>	<u>Road length %</u>
Up to 900 m	56.4	52.9	59.0	62.9
Up to 1 200 m	22.2	23.5	22.6	22.8
Above 1 200 m	21.4	23.6	18.4	14.3

This comparison confirms that road-net density decreases with rising altitude. It shows that road length distribution in the three latitudes does not conform but differs considerably from the corresponding percentages of forest area and total supply. At 62.9 percent the length percentage in altitudes up to 900 m is considerably higher than the percentage of supply. The road length percentage of 14.3 in altitudes above 1 200 m is lower on the other hand than the supply percentage of 23.6 by almost the same amount.

The distribution of the annual cutting figures in the various altitudes is roughly to be found between the supply and the road length percentages. Cutting figures are larger in the lower altitudes, smaller in the higher altitudes. The percentage of cuttings is, nevertheless, above the road length percentage at the highest level, which means that opening up considerably lags behind actual cutting activities.

<u>Altitude above sea level</u>	<u>Protective forest in production</u>			<u>Road-net density linear m/ha</u>
	Size of forest	Road length		
	<u>area (ha)</u>	<u>Km</u>	<u>%</u>	
Up to 900 m	54 518	624	19.3	11.4
Up to 1 200 m	69 438	653	20.2	9.4
Above 1 200 m	250 547	1 960	60.5	7.8

Here the decrease of road-net density with rising altitude is much greater even than in fully productive high forest.

Distribution of forest area, supply  
and road length at various altitudes

<u>Altitude above sea level</u>	<u>Forest area (%)</u>	<u>Total supply (%)</u>	<u>Road length (%)</u>
Up to 900 m	14.6	14.8	19.3
Up to 1 200 m	18.5	21.6	20.2
Above 1 200 m	66.9	63.6	60.5

The percentage of road length in protective forests at altitudes up to 900 m is 1.3 times as high as the percentage of supply in this altitude; for the highest altitude of above 1 200 m it is only 95 percent of the supply percentage, and 90 percent of the forest area percentage.

### 3. ROAD SPECIFICATION

<u>Type of roads</u>	<u>Fully productive high forests total road length</u>	
	<u>Km</u>	<u>%</u>
Public	29 728	32.5
Cooperative	38 132	41.7
Private	<u>23 550</u>	<u>25.8</u>
	91 410	100.0

Of all the roads in the fully productive high forest, almost one third is made up of public roads, just under one quarter are private and belong to individual forest owners, and the remaining 42 percent are cooperative roads.

<u>Type of roads</u>	<u>Fully productive high forests</u>					
	<u>Small, forests road length</u>		<u>Forest enterprises road length</u>		<u>Austrian State Forest Enterprise, road length</u>	
	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>
Public	24 738	40.1	3 564	16.0	1 425	19.1
Cooperative	33 262	53.9	3 801	17.1	1 069	14.3
Private	<u>3 683</u>	<u>6.0</u>	<u>14 908</u>	<u>66.9</u>	<u>4 960</u>	<u>66.6</u>
	61 683	100.0	22 273	100.0	7 454	100.0

### 4. ROAD WIDTH

<u>Road width</u>	<u>Fully productive high forests total road length</u>	
	<u>Km</u>	<u>%</u>
2 to < 3 m	51 585	56.4
3 to < 5 m	32 846	35.9
5 m and more	<u>6 979</u>	<u>7.7</u>
	91 410	100.0

<u>Road width</u>	<u>Fully productive high forests</u>					
	<u>Small forests road length</u>		<u>Forest enterprises road length</u>		<u>Austrian State Forest Enterprise, road length</u>	
	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>
2 to < 3 m	35 043	56.8	12 206	54.8	4 336	58.2
3 to < 5 m	21 828	35.4	8 375	37.6	2 643	35.4
5 m and more	<u>4 811</u>	<u>7.8</u>	<u>1 693</u>	<u>7.6</u>	<u>475</u>	<u>6.4</u>
	61 682	100.0	22 274	100.0	7 454	100.0

The percentage of roads with a carriageway width of 2 to 3 m in forest enterprises is only just under the figure for small forests.

From these data collected in all of Austria's forests, results can also be obtained for the federal provinces and communities. However, the margin of error is relatively high in calculations for small community areas, so that the data cannot be considered accurate. They are just an indication as to whether in these smallest units there is a tendency toward or away from the set targets.

When opening-up activities were first started in 1948, the planning objective was set at a density of about 20 linear m/ha (average figure for Austria's total area). The results conveyed above required a revision of objectives effected on the occasion of a seminar in the spring of 1977.

In 1975 a new Austrian Forest Act was passed which, among other things, includes a passage on the promotion of forestry in general. The individual sectors in which promotion is to be carried out are clearly defined and they include forest road building. The maximum subsidy given is 45 percent. In the highest altitudes above 1 200 m the road-net density is smallest, but supply is well above average. In order to stimulate the opening up of high forests, the Federal Ministry of Forestry and Agriculture issued guidelines in which the maximum subsidy of 45 percent stipulated in the law is granted only for forest roads at altitudes above 1 200 m. Roads below this altitude are just subsidized for 30 percent of their total costs. This public subsidy is allocated only if the applicant is qualified to carry out the project and if he does not have the necessary financial means himself.

Another kind of promotion is the granting of interest allowances. These are paid from the federal budget and help to pay the interest on agricultural investment loans granted by banks under special contract with the Federal Ministry. For this subsidy from public means the interest rate is supported so that in practice the applicant will pay an interest of only 5 percent. These loans are restricted to a term of 10 years and their amount must not exceed 60 percent of the total costs. In extreme situations, such as after snow break disasters, subsidies may be granted in any kind of combination; but 20 percent must be paid from the applicant's own purse.

To big forest owners - minimum size 200 ha - credits are granted from the so-called ERP Fund<sup>1/</sup>. This was created by the United States Government for the reconstruction of Europe after the Second World War. The fund passed into Austrian administration after 1955. Under the ERP scheme, loans of up to 70 percent of the total production costs are granted at an interest rate of 3 percent. The term of this loan is 15 years. The scheme also provides for forest machinery, such as lorries, de-barking machines and other machinery employed for timber harvesting, to be subsidized by an ERP loan. The term of these loans for machinery is only 5 years and interest is at 5 percent.

As can be seen from the figures mentioned previously, Austria already has a basic network of opening-up roads. However, this needs to be improved as far as density and altitude are concerned. Damage to the landscape caused by future opening-up activities will be more noticed by the general public than ever before. Preventive measures have to be taken to keep this damage to a minimum and objectives in opening up have had to be revised. In April 1977 a seminar was held at the Forestry Training Centre, Gmunden, for the purpose of studying the opening up of forests and the public interest.

<sup>1/</sup> European Recovery Programme

When entering difficult terrain and protective forests, the forester responsible for the planning and construction of roads will be increasingly criticized by public opinion. Forest roads are nevertheless necessary for careful management and for the preservation of our forests. Forest roads can be supplemented by cable devices, but they cannot be omitted. In order to find the most uniform answer to these problems, representatives at various administrative levels within the forest authorities and chambers of agriculture, the environmental association, the Austrian State Forest Enterprise, the Federal Forestry Research Institute, the Office for Torrent and Avalanche Control, private forest enterprises and civil engineering associations, and several experts in silviculture, forest protection and forest technology were invited to the seminar by the Federal Ministry of Agriculture and Forestry.

After two introductory lectures, of which the first conveyed the findings of the nature preservation experts, and the second those of the forest technology experts, four study groups were formed to discuss the answers to a questionnaire. The first study group was to represent the point of view of forest technology, the second that of the private forest enterprises, the third that of silviculture and forest protection and the fourth that of the forest authorities.

The group discussions were summarized and reported to all the other participants by a group speaker. The results achieved in the individual study groups were again discussed and the following general findings were agreed upon:

Contrary to general practice in the past, road-net density for the total area of the country should not be determined at the beginning of an opening-up programme. It should be adjusted to the structure and type of ownership. For the Austrian State Forest Enterprise a density of about 25 linear m/ha was recommended in order to keep timber transport costs down. Taking into account the high degree of mechanization, the recommended density for private forest enterprises was 30 to 35 linear m/ha. The small forests owned by farmers should have a target density of 40 to 50 linear m/ha in order to match this level of mechanization. About this last figure the representatives of the Torrent and Avalanche Control Office were sceptical because they believed that depending on the type of sub-base, building sites might exert a negative effect on erosion statistics.

Because of an increasing degree of mechanization, planning activities were rationalised and simplified. This was not always for the better. Since there is a general tendency toward the best work at the lowest cost, the quality of planning will also have to be improved in some instances, and for difficult projects general and detailed plans will have to be prepared. Construction defects which are due to imperfect preparatory work must be avoided in the future.

Young foresters will have to be trained in courses and seminars before working on road projects. Planting of the batter should be carried out as soon as possible not only because of its visual effect but also because a reinforcement of the batter has a positive influence on the road quality. Junctions of walking paths should be situated on forest roads. To realise the general opening-up objectives, the best combination between roads and cableways should be striven for.

In all groups there was a clear consensus of opinion on the desirability in a densely populated country like Austria of considerably intensifying public relations work and it was felt that for this purpose all media available should be employed. The general public

needs to be informed about all objectives and exigencies of forestry so that when various measures have to be taken, insight and understanding can be expected from the public.

At the planning stage a comparison of various possible routes is of paramount importance in order to achieve the greatest success with the least expense and damage to the landscape. Parking space and playgrounds should be given special consideration so that visitors find guidance in the forest. This means additional costs for private forest enterprises. The representatives expressed their hope that these additional costs in road construction spent to make environment more inviting would be borne by the general public. Continual attempts should be made to obtain the cooperation of various forest owners for road building projects. Such a joint venture would frequently make the routing less costly and more in line with needs. It would also be in the interest of the public authorities because higher efficiency might be expected.

Private forest owners cherish the understandable hope that promotion will not be different for the individual types of ownership and that they could expect adequate credits and subsidies to be granted. Their concern is understandable because help would for the most part depend not only on the financial situation of the State but also on the general public's understanding of forestry and its achievements. Since the public is frequently aware of forest road building and since, on the other hand, there is no doubt about the necessity for and advantage of opening up our forests, the group of private forest owners underlined their hope that future public relations work would focus on the usefulness and nationwide significance of such projects. It is not only the forest owner who profits from his forest but also many thousands of Austrian employees. They earn their living through jobs that are directly or indirectly guaranteed by forestry. Therefore, forestry deserves the concern of the whole nation.

The following points were brought out by the silvicultural group:

The higher the altitudes that are reached by opening-up projects, the more obvious will road building be for the general public. Road construction is welcomed by silvicultural experts because it is only by means of a road that a forest can be preserved and the necessary thinnings can be carried out; clear-cutting can be reduced and timber harvested by more powerful machines can be extracted and processed more easily (regarded as an advantage mainly by forest protection experts).

Torrent control representatives made observations both in favour of and against road building. The positive aspects included better accessibility of the terrain and the hydrological advantages of less frequent clear-cutting. Negative aspects were landslides, new water concentrations through insufficient discharge of water and, as a consequence, new centres of erosion.

The group of silvicultural and forest protection experts stated that forest road construction should be carried out according to the principle of rentability. Measures whose cost exceeded this rentability should be financed by the interested parties. (Such parties might include people living on or interested in tourism and other people profiting from forest roads).

As far as legislation was concerned, it was the general opinion that the legal basis for proper road construction is sufficient. It is essential to support readiness to implement legal provisions consistently, on the part of the authority as well as on the part of the forest owner.

Special importance was attributed to careful control of construction. In road construction, economic effects should harmonize with ecological effects; forest roads should be in line with nature and the landscape; terrain limits should be observed. To keep construction costs at a minimum cannot be the exclusive objective of such a far-reaching project. Safety measures are part of the construction, which explains why their costs are justly subsidized.

In this attempt to outline opening-up activities, as they are presently carried out in Austria, it is hoped that participants will find a basis for successful solutions to similar problems in their own countries.



Modern forest road construction techniques permit accessibility to forest areas in difficult terrain (Photo: R. Heinrich)

## GENERAL PRINCIPLES ON PLANNING OF FOREST ROAD-NETS

by

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### 1. INTRODUCTION

Forest roads which are usable by trucks have over the past few decades become the basis of forest management worldwide. Since these roads are the permanent elements in a modern forest transport system, careful planning and preparation is required.

Wide differences in local conditions preclude common specifications for road standards and road spacing. Therefore, it will be attempted in this chapter to explain terms and to describe reconnaissance procedures in general.

The forest road-net is designed with the intended or desired skidding methods in mind in order to obtain an economic transportation system with minimum overall cost. Principles of multiple-use management of the forest resources and environmental protection are taken into consideration in the plans.

The basic principle to be followed is: plan from the general to the particular. Therefore, the overall planning of forest development roads constitutes the framework for the detailed project.

A general plan for a forest transportation system including the forest road-net is normally elaborated only for large areas. The minimum size is about 500 hectares for intensively managed forests in the mountains of central Europe.

There is no other field in forestry where mistakes are as irreversible and permanent as in the planning of forest roads. Therefore, many variants of the feasible routes have to be taken into consideration by qualified and experienced specialists. Close cooperation with the local staff who know the peculiarities of the forest area is indispensable.

### 2. DEFINITION OF TERMS

#### 2.1 External and internal development

Access roads connect a forest area with the public road network, thus opening up the forest area from outside. Their primary function is to provide an external longitudinal link between forest areas and the public road system. These roads are normally situated in non-forested land and connect control points along the shortest possible distance. In Europe most of these access roads are already constructed and are public roads.

The main function of the forest road-net is to develop the forest area internally.

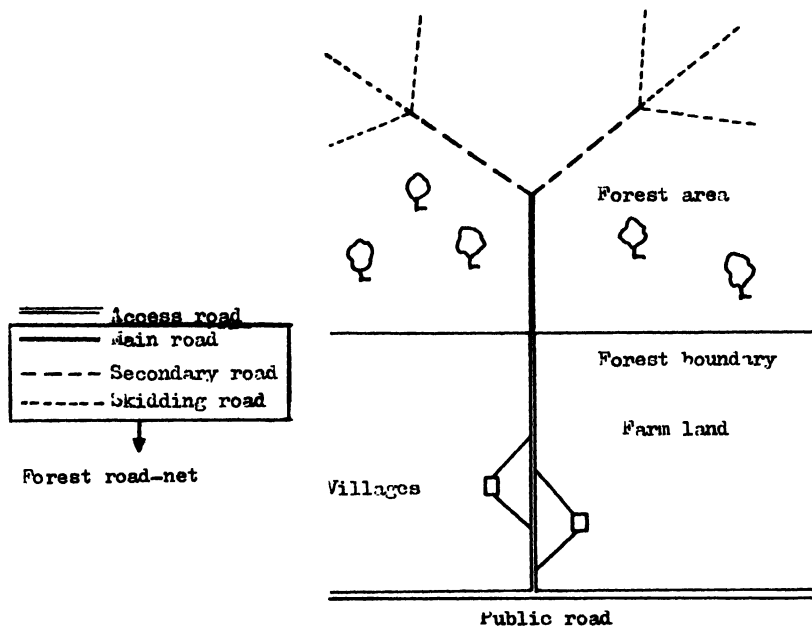


Fig. 1 - Scheme of forest road-net development

## 2.2 Road standards

### 'A' Roads (access roads and main forest roads)

These roads are destined for connection and development. They have a relatively high standard of construction and are usable by trucks on a year-round basis. In Europe they are usually single lane, while in tropical areas two lanes are frequent. Bituminous surfaced roads are used only where there is high traffic density.

### 'B' Roads (Subsidiary or secondary roads, feeder roads)

They subdivide the forest into individual logging sections and provide a connection between the landings and the main roads. They have a simpler standard of construction and are usable by truck only under favourable weather conditions.

### 'C' Roads (skidding roads)

These roads provide a connection between the felling sites and the landings. They have no surfacing and are usable only by skidding machines.



EXAMPLE OF FOREST ROAD CLASSIFICATION IN AUSTRIA

Specification	Type of forest road		
	Main road A	Subsidiary road B	Skidding road C
Width of formation b (m)	5.0 - 5.5	4.5 - 5.0	3.0 - 4.0
Width of carriage- way f (m)	3.5 - 4.0	3.0 - 3.5	-
Maximum gradient $\epsilon_{\max}$ (%)	9	10 (12)	12 (16)
Minimum gradient $\epsilon_{\min}$ (%)	2 - 3	2 - 3	3 - 4
Maximum gradient in adverse direction $g'$ (%)	6	8	10
Maximum wheel pressure P (t)	5 (7)	5 (7)	1 (1.5)

EXAMPLE OF FOREST ROAD CLASSIFICATION IN TROPICAL HIGH FORESTS  
(Heinrich 1975)

Road	Road use	Road width: carriageway including shoulders in m <sup>1/</sup>	Width of carriage- way in m <sup>1/</sup>	Min. curve radius in m	Max. gradient in %	Truck loads per day	Traffic speed in km per hour	Cost estimate in US\$ per m of road
Access road	Pick-up truck, permanent	9-12	7-10	50	6 (8) <sup>2/</sup>	More than 50	50-60	10-15
Main forest road	Pick-up truck, permanent	8-10	6-8	30	8 (10) <sup>2/</sup>	Up to 50	25-40	7-10
Secondary forest road	Pick-up truck, temporary	6-8	5-6	20	10 (12) <sup>3/</sup>	Up to 6	15-25	1-7
Skidding road	Wheeled skidder, wheeled tractor, crawler tractor		3.5-4.5					0.3-1
Skidding trail	Crawler tractor		3.5-4.5					0.05-0.1

<sup>1/</sup> In steep and difficult terrain the road widths given above have to be reduced considerably.

<sup>2/</sup> Maximum gradient in steep, difficult terrain for unloaded trucks when driving uphill.

<sup>3/</sup> Maximum gradient in steep, difficult terrain for a short distance.

### 2.3 Road spacing, road density and skidding distance

Road spacing (RS) is the average horizontal distance in m (metres) between the roads of a forest road-net (disregarding skidding roads).

Road density (RD) is the average road length per hectare in m/ha (metres per hectare) of a forest road-net.

Both terms are defined by means of simple formulae:

$$RS \text{ (m)} = \frac{10\,000}{RD} \quad \text{and} \quad RD \text{ (m/ha)} = \frac{10\,000}{RS}$$

Skidding distance (s) is the mean value of the theoretical skidding distance, depending on road spacing, topography and the skidding techniques applied.

Road density and skidding distance can also be estimated by means of the factor of "road efficiency"; see V. Segebaden (FAO):

RD (m/ha)

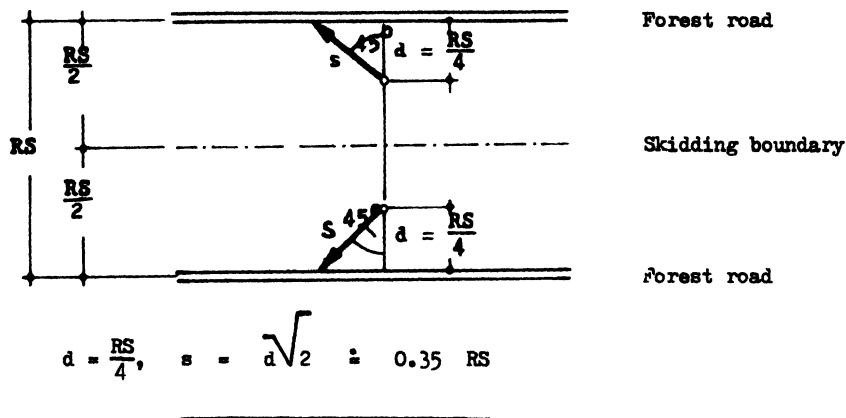
a = road efficiency factor: normally between 5 and 9  
4-5 for flat terrain;  
5-7 for hilly terrain;  
7-9 for steep terrain;  
9 and above for very steep,  
regular terrain.

s = average skidding distance (km)

The relationship of road spacing and the average skidding distance is explained in the following two examples:

#### 2.3.1 Example for flat terrain

In practice, the mean skidding distance does not correspond to the shortest possible skidding distance ( $d = RS/4$ ). According to Volkert, it is approximately 20-30 percent longer. For rough calculations it is sufficient to assume a 45-degree angle between the skidding direction and the forest road (see Figure 2).



Example for  $RS = 400 \text{ m}$  :  $s = 400 \cdot 0.35 = 140 \text{ m}$

Fig. 2 - Mean skidding distance in flat terrain

### 2.3.2 Example for mountain slopes

Wheeled tractors with a rear winch normally work on slopes of up to 35%. In steeper terrain skidding roads are required or cable extraction methods and/or ground skidding by means of gravity are applied. Therefore, the skidding boundary on a slope depends on the surface, the steepness and the techniques applied. When the actual skidding distance on steep slopes is calculated, the difference between the actual length on the slope and the horizontal projection on the map must be considered.

The following examples (Figure 3) are of uphill skidding by winch and downhill skidding by gravity in a farm forest with low mechanization:

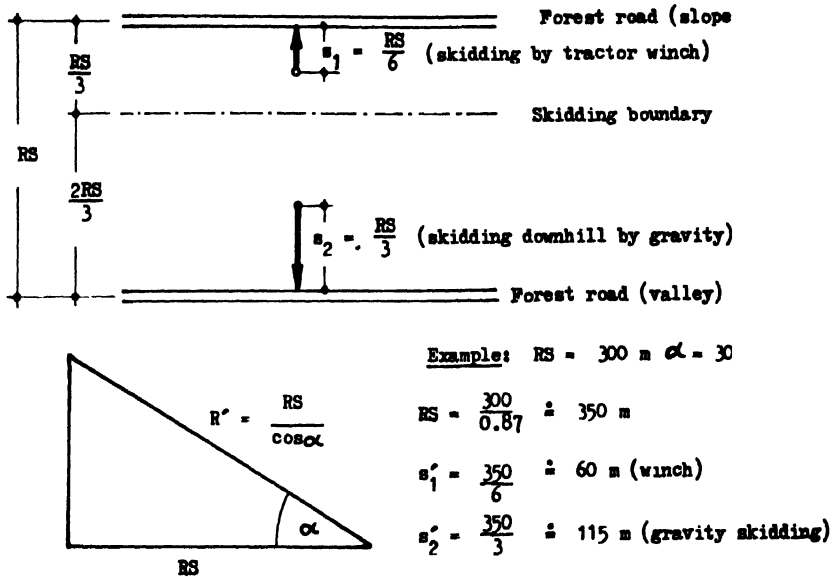


Fig. 3 - Mean skidding distances on mountain slopes for uphill and downhill skidding

#### 2.4 appropriate forest road density

The problem of choosing the right forest road density is important in theory but in practice it is difficult to solve.

The main objective of the general design of a forest transportation system is to find the most workable and economic road net with the lowest cost in the long run. Besides the closely interdependent costs for off-road and on-road transport, there are also considerations of the non-monetary values of multiple-use management and environmental protection to be borne in mind. Some models have been developed using mainly methods of cost-effectiveness-analysis and/or computer simulation. But none of these trials is very compatible with practical performance.

Numerous methods of approximation have been developed to estimate feasible equivalents of road density and road spacing.

The most important factors for comparisons of transport costs are:

average annual quantity of timber harvested per hectare

average skidding cost per hectare

average road cost per hectare (including construction and maintenance)

These costs can be used to calculate the transport cost of road-nets of different densities to find the scope of the lowest total cost.

Figure 4 shows the general relationship between road cost, skidding cost and total cost (sum-curve).

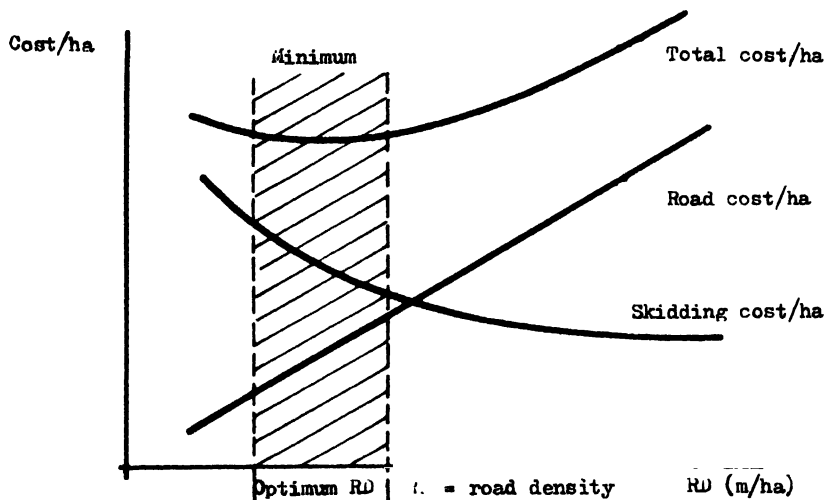


Fig. 4 - Optimizing the total transport cost

Using the method mentioned above, Koenig calculated theoretical optimum values for road spacing in Nordrhein-Westfalen of the Federal Republic of Germany:

Annual road costs	Annual increment of timber			
	(low) 3 m <sup>3</sup> /ha		(high) 9 m <sup>3</sup> /ha	
	flat terrain	hills	flat terrain	hills
low	700 m	450 m	400 m	250 m
medium	1 000 m	600 m	550 m	350 m
high	1 000 m	750 m	700 m	450 m

Assuming an average increment and average construction cost, an example of empirical recommendations for road spacing in Austria is given by the author:

Gradient	Terrain	Skidding	Large forest (>2 000 ha)	Medium-sized forest (200-2 000 ha)	Small forest (<200 ha)
0-15 %	flat terrain	wheeled skidder, uphill and downhill	500-600m	400-500m	300-400m
15-30 %	hills	wheeled skidder, downhill	500m	300-400m	300m
30-60 %	hills and mountains	wheeled skidder on skidding tracks, uphill cable skidding, downhill skidding by gravity	300-400m	300m	200-250m
> 60 %	steep	cable skidding, downhill skidding by gravity	400m	300-400m	300m

A comparison of the road density values for intense forest management which are presently found in Austria and which are the results of the Austrian Forest Inventory is of interest. The public road-net within the forest (except for highways) is included in these figures. The proximity of the small private forests to the public road-net largely explains their relatively high road density.

Type of ownership	Road density m/ha
Small privately owned forests	37
Medium and large-size privately owned forests	30
State-owned forests	22

## 2.5 Logging area and skidding directions

The overall design of the road-net usually covers a logging area for which the forest transport system is developed. One of the first steps in reconnaissance is to fix the boundaries of this area. This is relatively simple in mountainous terrain where the watersheds are marked by ridges. In flat and hilly terrain it is more difficult to determine because the natural boundaries are less pronounced.

The forest road-net should be developed in such a way as to take full advantage of gravity for skidding operations and transport. This is important in view of the rising cost of fuel. In some regions cable logging has resulted in extended ridge road systems since cable logging is easier uphill than downhill. But unless the terrain is extremely difficult the forest road-net should be developed from the lowest points of the logging area. The main roads should open up the valleys and the slopes should be subdivided into sections by feeder roads, beginning in the valleys. If such a road system is constructed, skidding downhill as well as uphill is feasible. A forest road system which is based mainly on ridge roads and uphill skidding is not the best solution in the long run.

## 2.6 Slope grades and classification of terrain

Slope grade	Classification of terrain	Performance
0 - 30 %	Flat and hilly terrain	Simple road construction, few rocks or none, only minor damage to the environment.
30 - 60 %	Medium hilly and mountainous terrain	
60 - 80 %	Steep terrain	Difficult road construction. With rising slope grade more rocks and damage; if the average gradient exceeds 70%, the question should be asked whether road construction is really necessary.
> 80 %	Very steep terrain	

## 2.7 Systems of forest development roads

Forest road-nets have as much diversity as the terrain itself. Nevertheless, there are some typical patterns and designs.

### 2.7.1 Flat terrain

The spacing of a road system in flat terrain can be kept fairly constant. Therefore, practical results correspond to theoretical models fairly well.



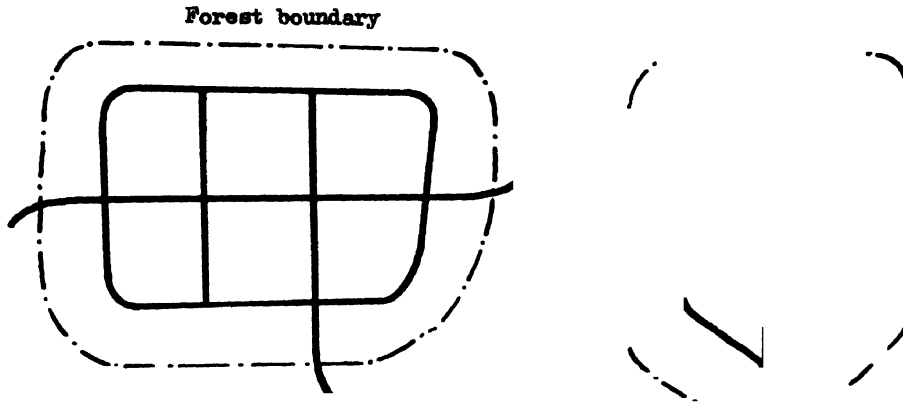


Fig. 5 - Two schemes of road-nets in flat terrain

## 2.7.2 Hilly and mountainous terrain

### (i) Valley roads

These are usually the basic main roads for the bottom of the valley and the ascending slopes. Bridges should be reduced to a minimum because they are costly to construct and to maintain.

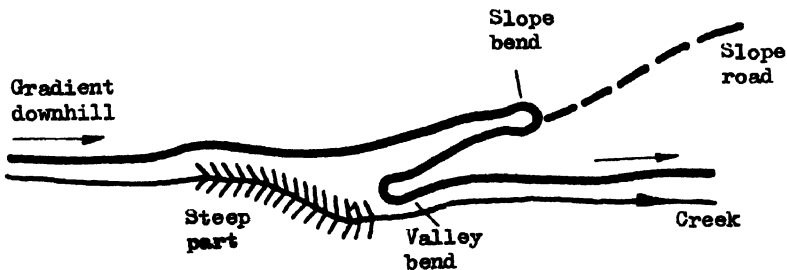


Fig. 6 - Valley road in a steep part (Serpentine valley bend and slope bend)

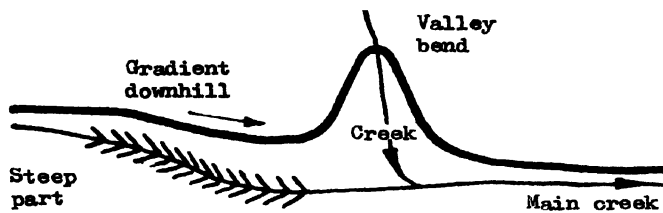


Fig. 7 - Valley road in a steep part (Bend in a side valley)

(ii) Slope roads

These start from valley roads and subdivide slopes. A distinction can be made between serpentine and diagonal systems depending on the slope grade.

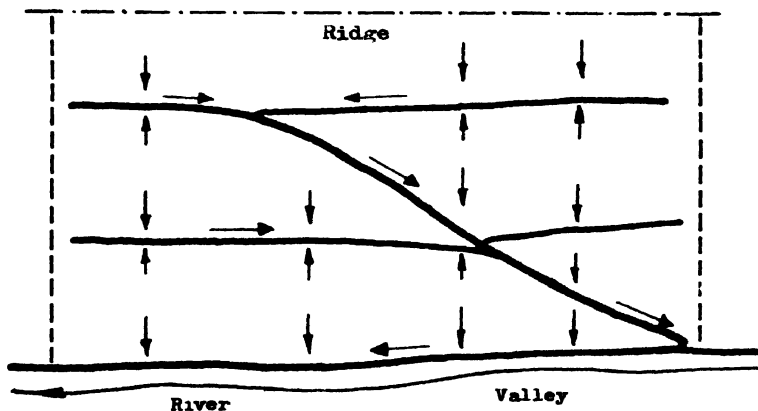


Fig. 8 - Diagonal system on gentle slopes

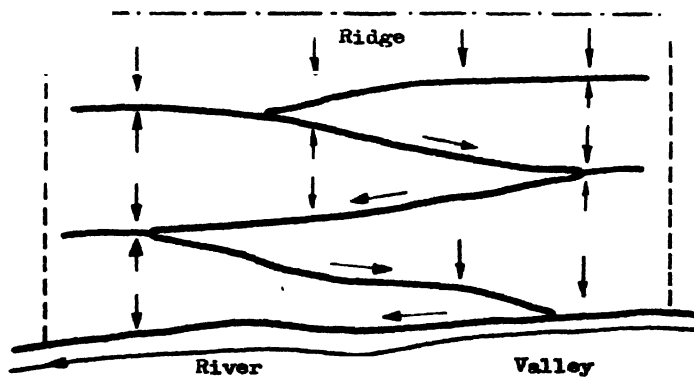
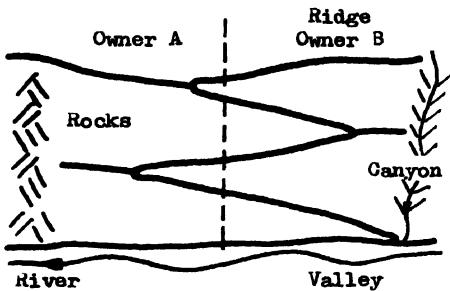


Fig. 9 - Serpentine system on steep and long slopes

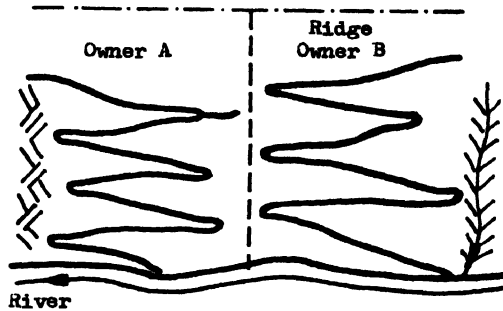
When forest road systems are planned on slopes, special efforts should be made to keep the number of bends to a minimum to avoid so-called zig-zag patterns. The owners of small forests in mountainous areas should cooperate to construct a common advantageous road system as shown in Figure 10, left side.

Cooperatively planned roads

Individually planned roads



C O R R E C T



I N C O R R E C T

Fig. 10 - Correct and incorrect development of a forest road system on a slope

(iii) Ridge roads

These roads represent the cheapest type in steep and irregular terrain. However, they open up the area to only a very limited extent and are used for uphill cable logging in difficult terrain. They should be planned only if the valleys are actually inaccessible or the slopes are too steep or unstable. See Figure 11.

Ridge

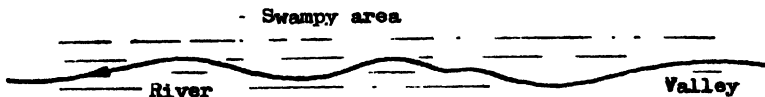


Fig. 11 - Forest road along a ridge

(iv) Mountain and hill tops

Circular roads can be located in suitable terrain to open up the tops of mountains and hills. See Figure 12.

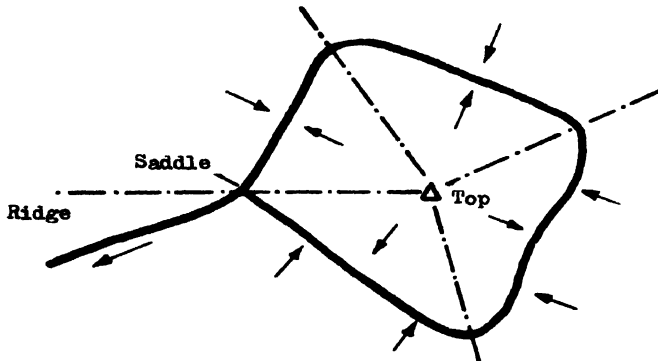


Fig. 12 - Circular road around a hilltop

(v) Valley basins

Valley basins in hilly or mountainous terrain are opened up by means of a main valley road and a circular road system on the slopes, provided that the terrain is not too difficult. See Figure 13.

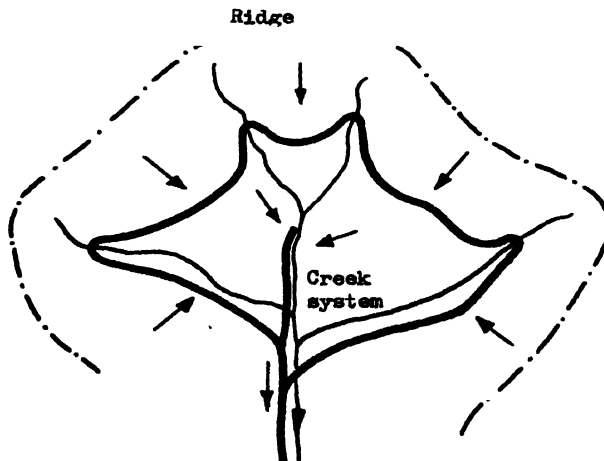


Fig. 13 - Forest road system in a valley basin

(vi) Skidding areas beyond inaccessible terrain

Such areas can sometimes be opened up from the opposite side by crossing the ridge at a suitable saddle point and using adverse gradient for part of the road.

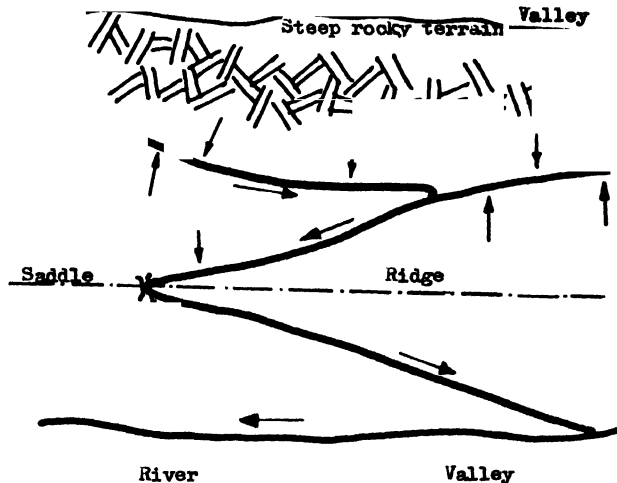


Fig. 14 - Road development from the opposite side

3. PRACTICAL PLANNING PERFORMANCE

3.1 Preparation

All available information about the area in question should be assembled as a prerequisite to the reconnaissance. This material should include, for example, topographic maps and aerial photographs, geologic, hydrological and soil data, maps of ownership and plans of multiple land use, forest management and forest transportation.

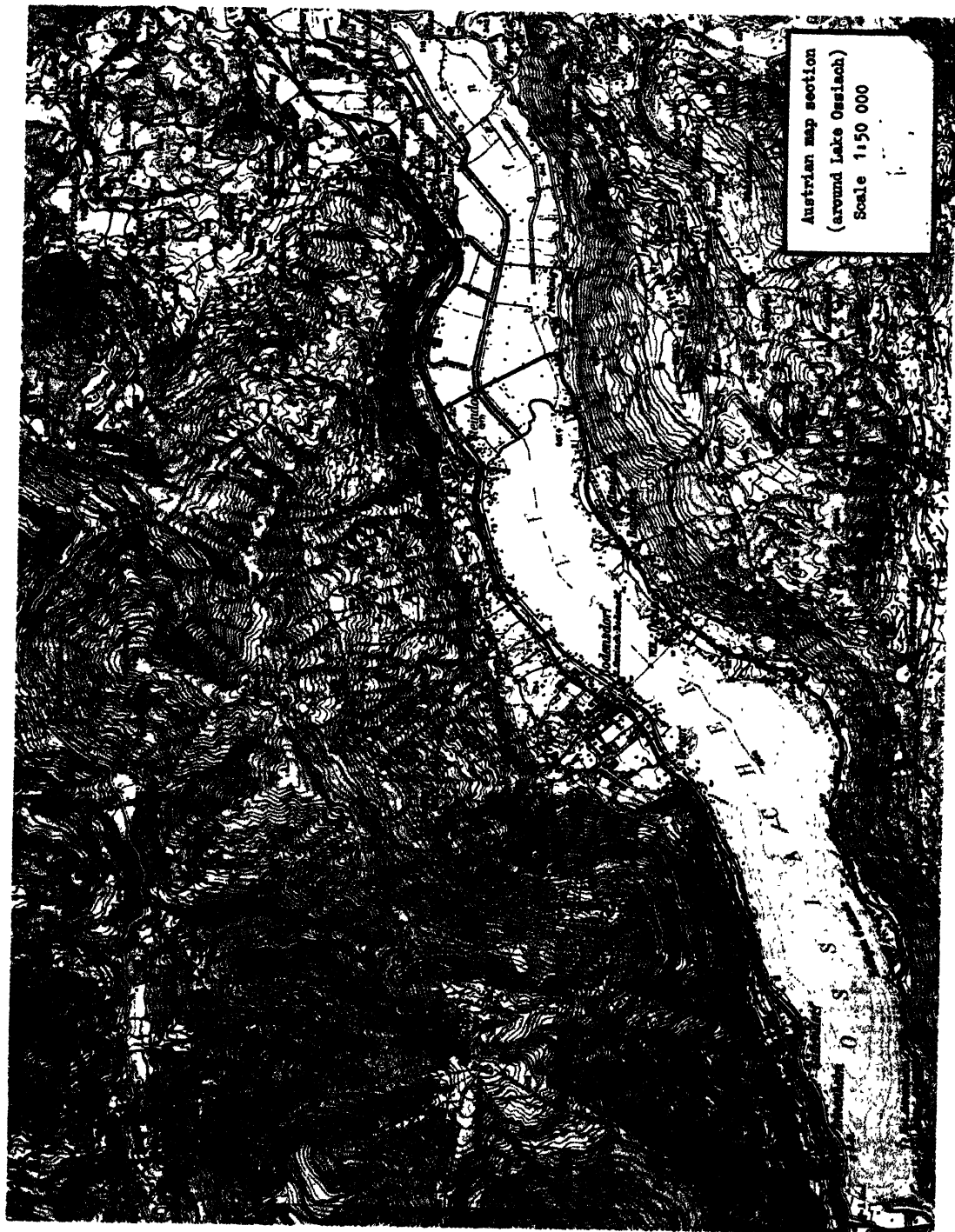
3.1.1 Topographic maps

Modern topographic maps are made from resource photography and are indispensable for reconnaissance in large areas. In Europe topographic maps of high standard and accuracy are normally provided by the national survey authorities. The usual scales are 1:50 000 or 1:25 000. The maps have contour lines with intervals of 10 or 20 m.

3.1.2 Special maps

Modern forest maps with scales of 1:10 000 or 1:5 000 show many important details of topography, streams, timber cover, age classes and existing transport systems.

Geological maps are very useful and provide a general survey of soils and sub-soil conditions.



### 3.1.3 Aerial photographs

Aerial photographs are often used in addition to topographic maps. They show much detail such as land use and forest cover.

Aerial photographs are still the sole source of reconnaissance information in many countries. In flat and slightly rolling terrain these photographs can be directly used as "photo maps" since they reveal distances. For mountainous terrain aerial photographs should be transformed to orthophoto maps. An ideal type of material is the orthophotomap with contours, which combines photographic effect with map accuracy.

The normal scale of aerial photographs used during fieldwork is about 1:15 000. Photomaps are enlarged to scales of 1:10 000 or 1:5 000.

### 3.1.4 Pre-reconnaissance data

Besides maps and photographs many other types of information are required. For overall knowledge of the area, data on the location, climate and the size of the area are collected. Geological and hydrographic data details of forest management (timber resources, growing stock, increment, logging costs, analysis of the existing transportation system) are also required. Practical experience of previous forest road construction in the area is very useful (sub-soil, gravel deposits, cost).

Special consideration should be given to problems of environmental protection and multiple-use coordination in cooperation with the competent specialists.

## 3.2 Field reconnaissance

No fixed methods of field reconnaissance can be recommended since local conditions and objectives vary widely. But it is emphasized that a thorough personal reconnaissance conducted on foot is indispensable in order to study the peculiarities of the terrain and the feasible routes. This personal engagement of the responsible engineer in close cooperation with the local staff must not be replaced by studies of maps, aerial photographs or even helicopter flights which can only complement a careful reconnaissance.

### 3.2.1 Work procedures

If modern maps with contours are available, general paper drafts of several variants of the forest road-net can be plotted quite easily. But a first overall reconnaissance is necessary beforehand in any event.

The main roads are normally located in the main valleys and the slopes should be subdivided by means of feeder roads as has already been mentioned. Account must be taken of the points of junction with the public road-net, the terrain and the control points, the recommended grades and road spacing.

The most important part is the following thorough reconnaissance to verify the preliminary drafts. If modern maps are not available, the work begins immediately with a thorough field reconnaissance.

The activity should be carefully planned in advance as regards timing and organization. Large areas must be divided into several planning units. Problems of climate, travelling, housing, supply of food and drinking water must be taken into consideration.

During this thorough reconnaissance the engineering crew must walk along all main and side valleys and cross the slopes and ridges of the area. The actual terrain is carefully checked against the maps and photographs or - if this material is not available - it

is noted in drawings and sketches. All relevant control points and their altitudes are checked:

Positive control points are important as well as advantageous places for road construction or logging. These are bridging points, saddles on ridges, gentle slopes for better alignment, suitable places for switchbacks and landings. Also, gravel deposits which can be developed within the road system are very important especially for use on soils with low-bearing capacity.

Negative control points such as steep slopes, rock, swamps, unstable slopes, deep canyons and very irregular parts of the terrain are disadvantageous and should be avoided if at all possible.

During this field reconnaissance the terrain is explored in detail. Preliminary paper (map) locations are corrected or feasible routes can be directly selected in the field. Again it must be emphasized that all feasible routes should be studied thoroughly. Final comparisons and general cost estimates lead normally to only a few feasible variants of the general road system.

It is recommended, even for general plans, that the corridors of the selected main routes be checked by means of a thorough field control. In mountainous terrain where the lines are "grade controlled", the engineer with his crew (two helpers and two brush cutters) locates trial lines by means of clinometer (grade) and drag rope (distance). These lines should be marked on trees with plastic flagging. During this phase unexpected obstacles may still be found, so corrections lead to feasible locations.

The final design of the general plan for the forest road-net should be selected by the location engineer, the local staff and specialists on forest resources, environment and multiple land-use in cooperation.

### 3.2.2 Instruments and equipment

Nowadays modern hand-held instruments are mainly used in forest road engineering. These instruments are small but accurate.

#### Instruments and equipment

#### Use

Barometric altimeter	Altitudes above sea level
Clinometer	Grades and side slopes
Compass	Bearings (Azimuth)
Drag rope (nylon), 50m	Distances
Pocket stereoscope	Stereoscopic view of aerial photographs

#### Additional equipment:

engineer's case with pencils,  
rulers and scales, protractor,  
field notebook, maps and  
aerial photographs,  
plastic flagging (tape)



Instruments recommended:

Barometric altimeters

THOMMEN pocket altimeter (made in Switzerland) is a small pocket instrument for general surveys with an accuracy of  $\pm 20$  m. Price about US\$150.

PAULIN altimeter (made in Sweden) is a very accurate instrument with an accuracy of  $\pm 5$  to 10 m. Price about US\$1 000.

Clinometers

MERIDIAN clinometer (made in Switzerland) is a small pendulum device with a fixed optical system. The most suitable model, MC 1002, has two lenses for separating uphill and downhill readings to 100 percent both ways. Price about US\$130.

SUUNTO clinometer (made in Finland) is a small pocket instrument with a moving scale card. Normally the type FM-5/360 PC with scales of percent and 360 degrees is used. Price about US\$70.

Compasses

During field reconnaissance, compasses with a protractor base can be advantageously used. There are many types. The following mentioned instruments can be recommended:

BEZARD (made in Germany). Price about US\$90.

SILVA (made in Sweden). Price about US\$30.

For more accurate surveying purposes compass instruments without a protractor base are recommended.

SUUNTO (made in Finland) is an excellent instrument with a reasonable price of about US\$60.

MERIDIAN (made in Switzerland). Price about US\$90.



Engineer's case with instruments (Photo: O. Sedlak)

### 3.3 Elaboration of the general project

The general project represents the results of the field reconnaissance and route selection. The paperwork consists of a written part and survey maps and plans.

#### Paperwork

The Technical Report consists of the following:

- a. Summary - mainly in the form of tables (routes, length, costs;
- b. Description of the area and of the previous existing management and logging systems;
- c. Reasons for developing a new road system and improvements expected. Description of the new transport and logging system;
- d. Description of the planned forest road system (principles of the design and considerations of road spacing), details of the new individual routes;
- e. Recommended methods of construction and organization. Timetable;

- f. General cost estimate. If no local data are available, approximate cost may be determined by using Sundberg's formula:

$$C_i = 230 + 17 \times SL + 660 \times ST_i + 30 \times SL \times ST_i$$

Where:

$C_i$  = direct cost in US\$ per km for road standard "i"  
(supervision and overhead excluded)

SL = mean side slope in percent of the terrain

$ST_i$  = road standard, 0 for skidding trails, 1 - 2 for secondary roads, 3 for main and access roads

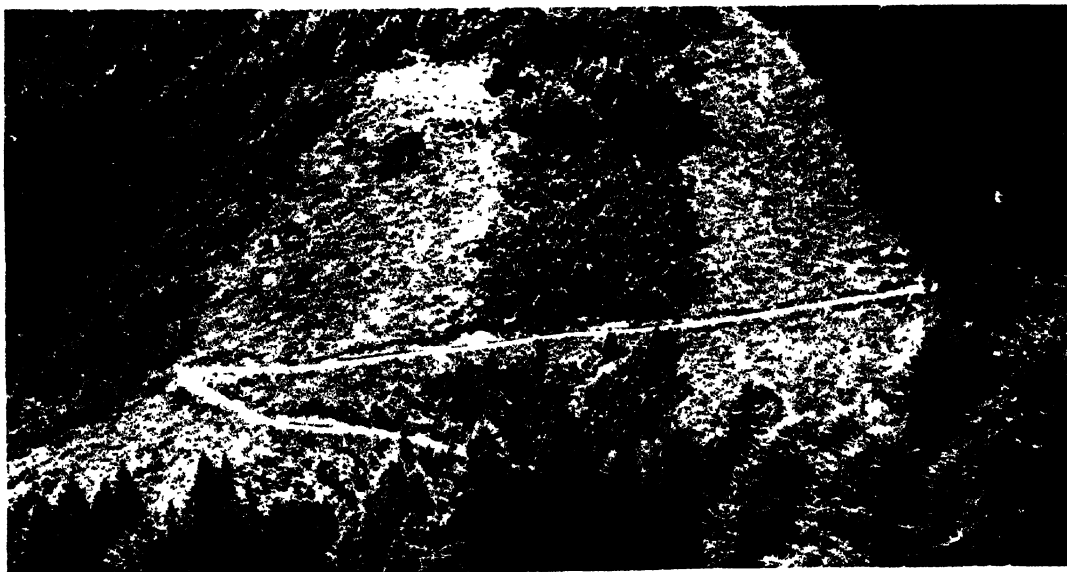
#### Drawings and plans

Section of the topographic map (scale 1:50 000) with the draft of the planned road-net.

Survey map (scale 1:10 000) with the detailed draft of the planned road system.

General cross-sections (scale 1:50).

General drafts of structures (culverts, bridges, retaining walls, scale 1:50).



Well planned forest road networks allow intensive forestry operations  
(see small clearcut areas next to regenerated and mature stands)  
(Photo: R. Heinrich)

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Well aligned forest road in very difficult terrain with revegetated fill slope  
(Photo: R. Heinrich)

## LOCATION AND COSTING OF FOREST ROADS

by

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### GENERAL REMARKS

This chapter deals with the location of forest roads and the elaboration of projects only for mountainous country.

The more complicated and expensive the road construction, the more intense and precise the planning methods which should be applied. Precise planning methods are required where roads are to be manually constructed, as still occurs in countries with underemployment and low wage costs; a precise location and design according to the classical engineering method could be established. This procedure includes a preliminary survey of the routing corridor along the gradeline, the processing of strip contours, levelling, the survey and plotting of cross-sections, mapping and designing on paper, final location and mass balancing.

Simpler methods of location have been developed for the mechanised construction of forest roads in the mountains of Austria. Normally the location of the gradeline (in Austria called the zero line) is sufficient where the gradient is the controlling factor. Since forest roads are constructed by machines with high performance, an exact costing of the earthwork is not required.

To find the most feasible route, however, it is necessary to run several trial gradelines. Such simple but expedient methods must not be confounded with careless planning, and they require skill and experience.

Since mechanised road construction is most frequently used, this simple gradeline method will be discussed during the course.

### LOCATION AND DESIGN

The location and design of a forest road may be divided into two phases:

#### Direct location in the field

In hilly or mountainous country the gradeline of a forest road is located directly in the terrain. In flat country it is mainly the horizontal alignment which is the controlling factor and the tangents are located depending on the general design.

Textual elaboration: technical report, drawings and cost estimates.

This textual part of the project contains the information necessary for construction and supervision as well as for review and approval.

## 2.1 Location

### 2.1.1 Location in flat or rolling country

In the same way as in mountainous country several variants of alignment within the general selected path of the road have to be studied to find the best route. The final tangential alignment of the centreline is staked with preference given to a curvilinear alignment rather than to very long tangents (see Fig. 1). The points on the curves are determined by means of the deflection angles, the radius and curve tables. Care should be taken to achieve minimum radius, smooth transitions and minimum gradient.

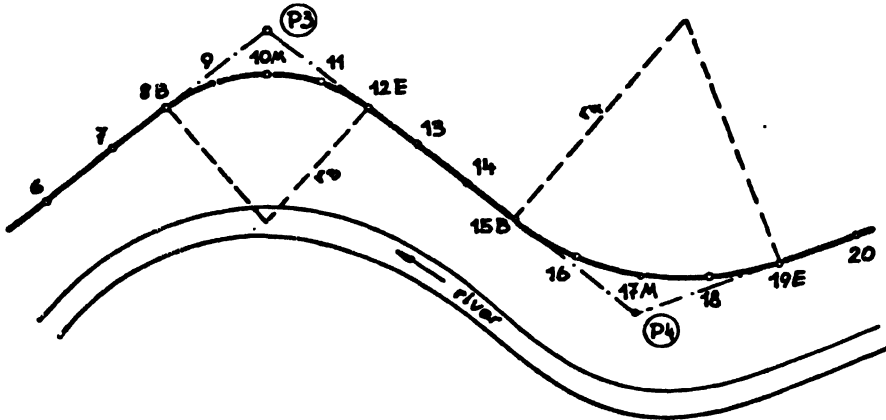


Fig. 1 - Alignment in flat country

- B and E - beginning and end points of curve
- M - middle point of curve
- P - polygon point

For secondary roads parabolic bends which are simply staked can also be employed.

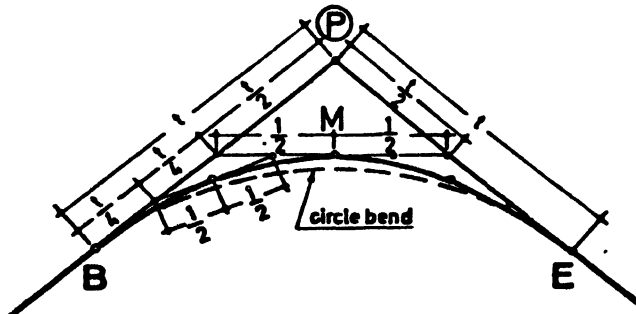


Fig. 2 - Parabolic curve

Instruments used: ranging poles (rods), steel or fibreglass tapes, drag rope, pocket compass, altimeter, theodolite or olinometer or surveyor's level.

### 2.1.2 Location in hilly and mountainous country

Forest roads in hilly and mountainous terrain are mainly grade-controlled and situated slopes. The gradeline which is the guideline for the mechanised road construction is staked directly in the field and is a staked line with the required gradient adjusted to the topography of the terrain. It represents the intersection between the subgrade of the road and the slope.

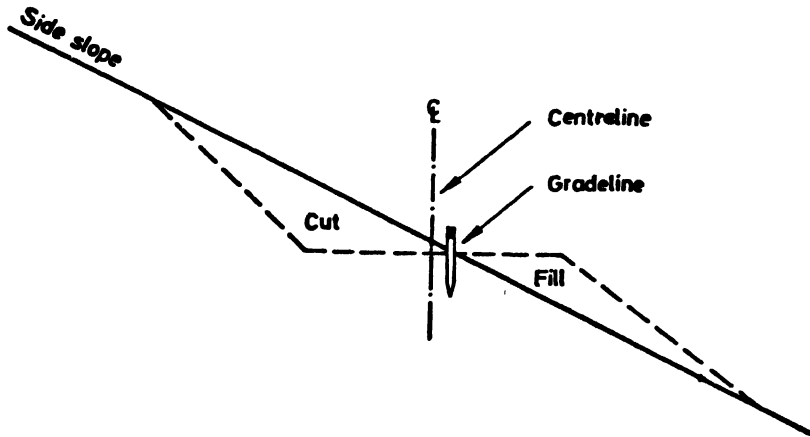


Fig. 3 - Position of the gradeline

The gradeline can be quickly and accurately staked by means of a hand-held olinometer. determine the best route it is recommended that one or more trial lines be run. These only flag lines marked by tying coloured plastic flagging to trees or branches.

The centreline is additionally staked only along difficult sections of the route where moment and horizontal control are important factors (e.g. in bridge locations, embankments, g outs in side ridges).

#### 2.1.2.1 Gradeline surveying techniques

For staking the gradeline the olinometer and a suitable target (painted plywood or minium sheet, size about 30 by 20 cm) are adjusted to the same height on two poles.

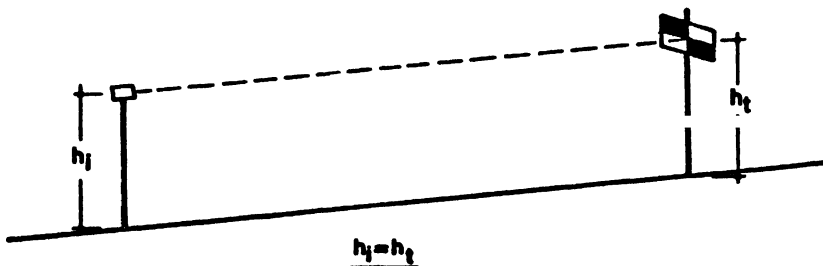


Fig. 4 - Clinometer and target

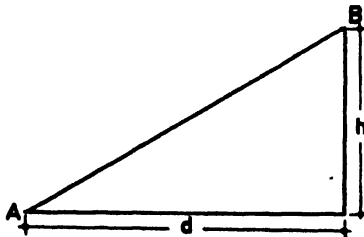
This simple equipment has to be checked before use. Two points are fixed on the ground at a distance of about 20 to 30 m and the gradient is measured both uphill and downhill. If the readings are equal then the adjustment is correct.

The surveyor needs a crew of one target man and about three helpers for cutting underbrush and staking. He always walks ahead of the crew and aims his clinometer back to the sighting mark. The distances between the points of the gradeline should be fairly equal (30 to 50 m for flagging, 20 to 30 m for staking).

The maximum gradient for downhill transport should not exceed 9 to 10 percent for main roads or 12 percent for secondary roads. Where uphill transport is required the maximum grade should be 6 to 8 percent. A minimum grade of 2 to 3 percent is necessary for good drainage. A level grade should never be used over a long distance because precipitation water will remain on the road and therefore the road will be damaged by traffic and problems for traffic easily occur.

During the first trials in the selected path of the road the surveyor determines the intermediate control points and the grades required. A pocket altimeter and a 50 m drag rope are useful aids for longer routes.

The individual gradients between control points are computed by means of the difference of altitudes over the distance.



$$g (\%) = \frac{h}{d} \times 100$$

h ... difference of  
altitudes B - A

d ... horizontal distance

Fig. 5 - Gradient between control points

In case it is necessary to reduce or to increase the gradient of the gradeline, the maximum difference between two of its grades should not exceed 3 percent provided the average distance between the stakes is about 20 to 30 m. Smooth transitions in the road profile will be obtained in this way. This rule must be observed especially in laying out switchbacks and in the transition from elevation to depression ("crest" - "valley") or vice-versa.

The gradeline has to be staked as closely as possible to the future centreline to avoid major differences of grade between the gradeline and the final road. In irregular country with ridges and valleys the gradeline reflects the breaks in topography more clearly and is longer than the final centreline. Allow for it and reduce the gradient! (see Fig. 6) A common mistake made by inexperienced personnel is to set stakes too far up depressions or on the outside of ridges, keeping a constant grade. The gradient in these curves will be too steep.



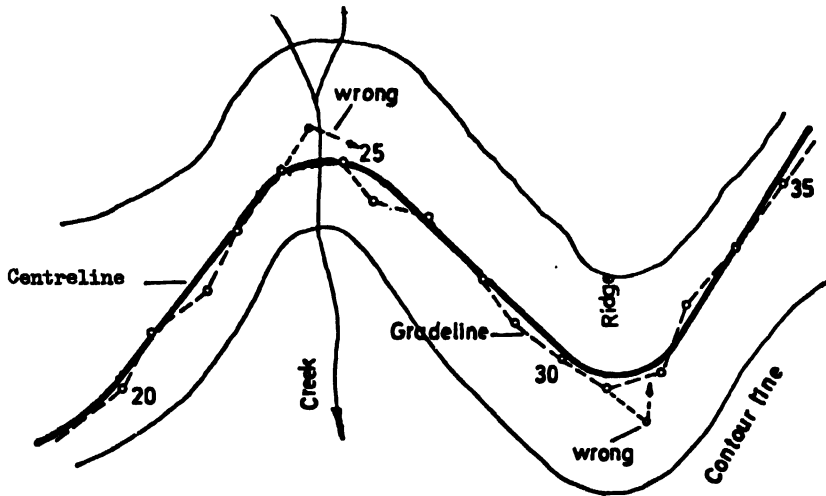


Fig. 6 - Location on a slope

"Valleys" in the road profile should be located across drainage depressions or torrents which will endanger the road during heavy rainfall. Thus, overflow water will be limited to these sections and major parts of the road will not be destroyed.

A switchback ("hairpin bend") is located as shown in Fig. 7. The centreline is additionally staked, using the tape. The maximum side slope should not exceed 40 percent. Suitable places in steep terrain are control points.

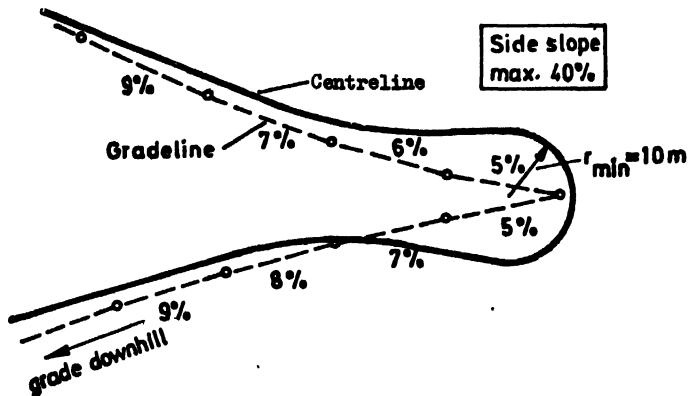


Fig. 7 - Location of a switchback

### 2.1.2.2 Method of locating the gradeline

A feasible path for the road is discovered by reconnaissance, so the surveyor has some idea of the general conditions, the control points and the ruling grades of individual sections. Nevertheless time would be wasted by driving in stakes during the first trials since corrections are usually necessary. Therefore, it is recommended that the location and the survey be divided into four stages:

1. A trial line with the estimated grade is flagged, without using a target and poles. The engineer sights back on the helper who should carry a sighting mark at the eye height of the surveyor (helmet). A drag rope is used to determine roughly the distances between control points. The line is marked by flags. This first trial line will not reach the desired control point and the grade will have to be corrected by calculating the height difference over the distance:

$$\text{Correction of grade} \quad \pm g (\%) = \frac{\Delta h}{d} \times 100$$

It should be mentioned that the difference between slope and horizontal distance of the gradeline is so small that it can be ignored.

2. In the case of a major difference, a second gradeline is run, using the improved gradient on the way back. A different colour flagging should be used to avoid confusion.

3. The two preceding trials can be regarded as a detailed reconnaissance. The final location can now be started using the clinometer and target adjusted, with poles.

The surveyor notes the following data in his field book during location of the road: number of the stake, the gradient, representative side slope, estimated rock component, additional mass of earth and rock which exceeds the normal profiles, description of terrain, culverts and structures (see Fig. 8).

Stake		14 cm					14 cm	
		from	to	Gradient g (%)	Distance d (m)	Bearing b (°)	Side Slope s (%)	Rock Excavation r (%)
21 cm								

Fig. 8 - Model for the field book

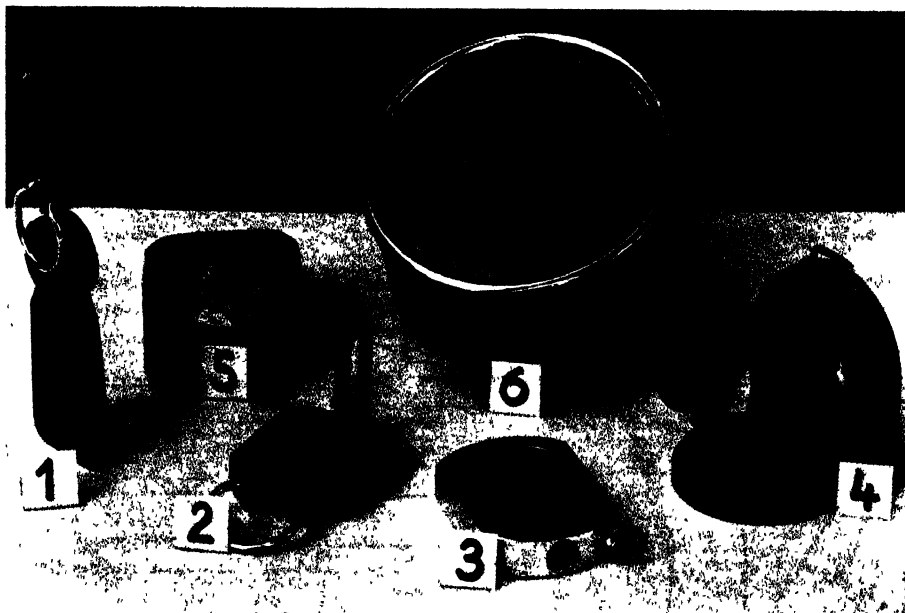
4. The staked gradeline is surveyed using a compass and tape, with the surveyor walking back over the route. Again he goes ahead of the crew and sights back at the target. By using a second signal ahead, he can check his bearings with the reverse scale of the compass. Both bearings are noted and differences should not exceed 1 degree.

A tape crew of three men measures the distances between the stakes. The readings are rounded down to full decimetres.

During this fourth stage the surveyor has only to note the bearings and distances.

#### 2.1.2.3 Instruments

The instruments described for general development of forest roads are also used for location and survey. Instead of a drag rope a tape (30 or 50 m, steel or fibreglass) is used to measure distances accurately.



Survey instruments (Photo: O. Sedlak)

#### 2.1.2.4 Performance

The level of performance in detailed field reconnaissance, location of the road and survey of gradelines depends on the accessibility of the terrain, on the topography, on the forest cover and last but not least on the experience of the road engineer and his crew. The following data can be used for estimates:

<u>Terrain condition</u>	<u>Personnel required</u>	<u>Time required</u>
Normal (forests in moderate climate, easy terrain)	1 engineer 3 workers	5 - 7 hrs/km 15 - 20 " "
Difficult (forests in tropical areas, difficult terrain)	1 engineer 5-6 workers	8 - 12 " " 40 - 60 " "

## 2.2 Textual elaboration of the project

The field data on the direct gradeline location are evaluated for adequate plans ("paper location"). A technical report with estimates of earthwork quantities and costs is also prepared.

### 2.2.1

A section of the topographic survey map (scale 1:50 000 or 1:25 000) shows the general location of the planned road within the existing transport system.

The gradeline projection is shown in a detailed map section (scale 1:10 000 or 1:5 000). The gradeline is plotted on transparent paper together with checking points on the map and the centreline is drawn as a freehand line close to the gradeline. This line has to be critically examined as regards horizontal controls (alignment, minimum radius) and feasibility. Several cross-sections at critical points will improve this paper location.

The final design is made in sections of 100 m each, using a divider, and is transferred to the master sheet of the map. Culverts and structures as well as landings and peculiarities of the terrain are drawn in the map using simple symbols.

In copies of the design plan the roadline is traced out in red ink. Rivers and small creeks are traced in soft blue pencil and ridges in brown. Forest boundaries are drawn in green. The skidding directions can be shown with arrows.

Typical cross-sections for earth and rock are designed as standard drawings for the construction. See Fig. 9.

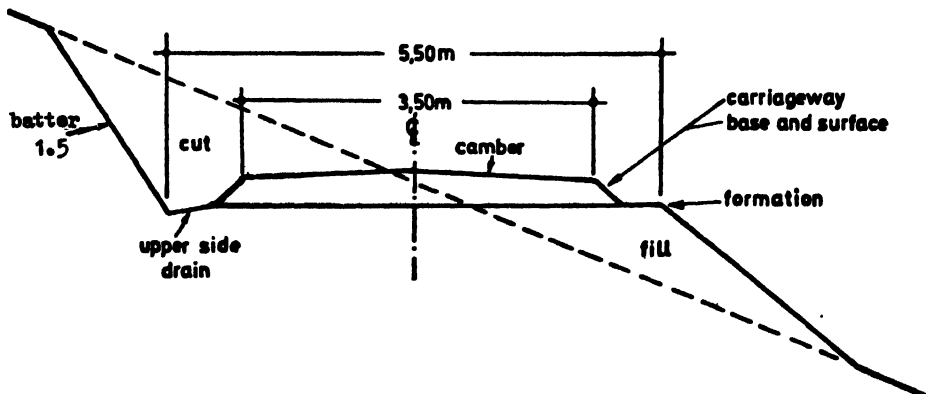


Fig. 9 - Cross-section

Fig. 10 - Map section of forest road "Piesslinggraben", Upper Austria  
(Scale: 1:5 000)

A profile of the gradeline is not usually plotted provided the direct field design of all vertical checkpoints is correct. Only a table in the form of a written grade profile is prepared, as illustrated below:

Stake	Station (hm)	Distance d (m)	Gradient g (%)	Remarks

### 2.2.2 Technical report

This report contains:

- description of the forest area (situation, geological conditions, topography, size, forestry data)
- existing transport system (logging and skidding methods, long-distance transport, costs)
- transport system to be developed
- description of the project
- construction (machinery, equipment, methods, organisation)
- written grade profile

While all what has been said up to now concerns the more technical aspects of locating a forest road and preparing the ground for its construction, the road engineer generally has to "prepare the ground" in another sense, that is, "to cost the activity" as explained hereafter.

### 2.2.3 Estimating the costs of construction

Costs for mechanised forest road construction are fairly similar despite wide differences in local conditions. Within certain limits, the costs for mechanised earthwork and transport are comparable.

However, local conditions do affect economic performance. In countries with low-wage cost and underemployment, modern machinery and equipment are relatively very expensive, especially with regard to rising prices for fuel. Here manual or only partially mechanised construction may still be the best solution. In a combined constructional method the major earthwork is done by machines, and only the minor earthwork (e.g. shaping out slopes, drains, culverts) is done by hand.

#### 2.2.3.1 Costs of preliminary work

##### Clearing the road corridor

The costs of clear-cutting the road corridor are not normally allocated to construction cost if the timber can be used. The corridor has to be cleared of branches and underbrush within the clearing limits, and the material deposited at the downhill edge of the roadway.

### Preblasting of stumps

If explosives are available, it is recommended that all stumps with diameters of more than 40 to 50 cm be preblasted, especially in flat country. On slopes only the stumps close to the gradeline are blasted. Average cost per stump is about US\$ 4-6. Blasting stumps is not economic if a heavy bulldozer (for instance the Caterpillar D 8) is employed.

### Drains

Wet areas should be drained by a fishbone system of drains some weeks before the earthwork is started. The current average cost per metre is about US\$ 0.8-2.0.

### 2.2.3.2 Costs of earthwork

Bulldozers with A- or S-blades are still the most important machines in forest road construction. These machines combine high performance with low cost of production. However, in steep terrain bulldozers cause considerable damage by sidecasting material. To meet the demands of environmental protection, therefore, hydraulic excavators are being increasingly employed in mountainous terrain.

Several methods of calculating the costs of earthwork can be applied:

- a) Calculating the quantity by means of side slopes and standard cross-sections which can be easily designed for various roadbeds (for examples referring to Hafner, see Figs. 11 A and B). The costs are calculated on the basis of the total volume and the cost per cubic metre;

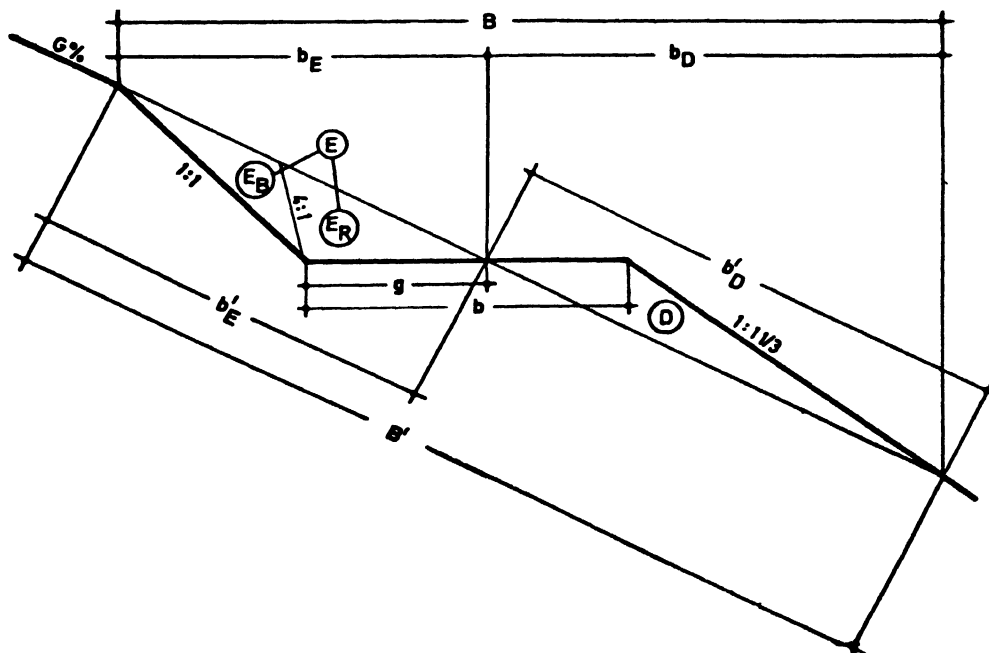


Fig. 11 A. Cross-section (slope profile) of earth - Example for  $b = 4$  m  
(ref. to Hafner)

Earth

G %	g m	b m	$m^3/m$ $E$	$m^3/m$ $E_R$	$m^3/m$ $E_B$	$b_E$ $b'_E$ m	$b_D$ $b'_D$ m	B B' m
20	2.70	5.30	0.91	0.77	0.14	3.35 3.40	3.65 3.70	7.00 7.10
30	2.70	5.30	1.56	1.18	0.38	3.85 4.05	4.30 4.50	8.15 8.55
40	2.30	4.40	1.76	1.17	0.59	3.85 4.15	4.50 4.85	8.30 9.00
50	2.30	4.20	2.64	1.51	1.13	4.60 5.15	5.80 6.50	10.40 11.70
60	2.40	4.10	4.32	2.03	2.29	6.00 7.00	8.75 10.20	14.80 17.20
70	2.70	4.00	8.50	3.09	5.41	9.00 11.00	19.70 24.00	28.70 35.00

Fig. 11 A. Calculation of earthwork costs: earth

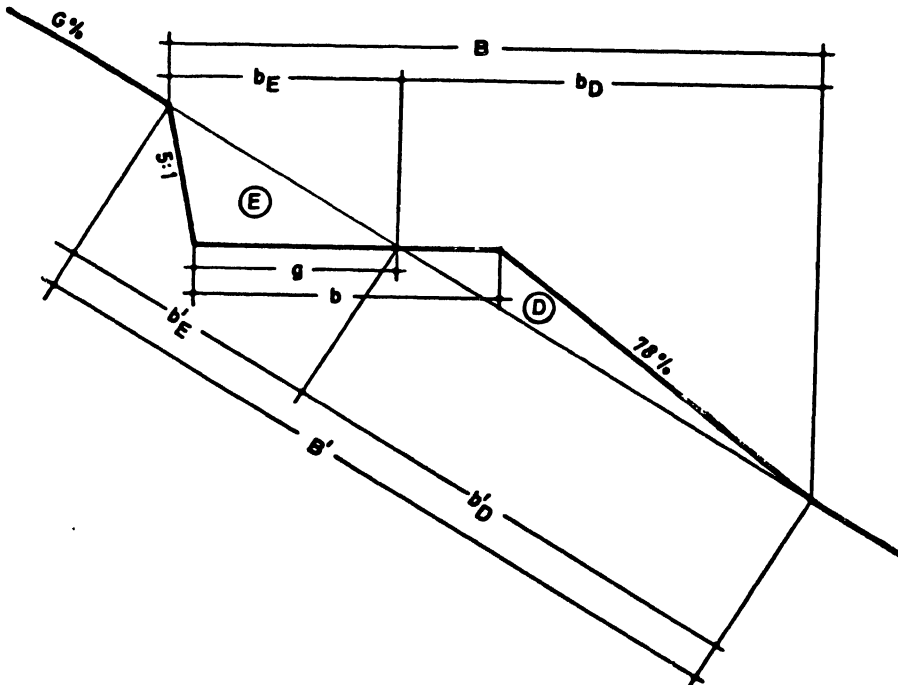


Fig. 11 B. Cross-section (slope profile) of rock - Example for  $b = 4$  m  
(ref. to Hafner)



**Rock**

$\alpha$ %	$g_m$	$b_m$	$m^3/m$	$\frac{b_E}{b'_E}$	$\frac{b_D}{b'_D}$	$\frac{B}{B'}$
40	2.50	4.50	1.36	2.70 2.95	4.00 4.35	6.75 7.30
50	2.50	4.20	1.74	2.80 3.10	4.75 5.30	7.55 8.40
60	2.60	4.00	2.30	2.95 3.45	6.20 7.25	9.20 10.70
70	3.00	4.10	3.66	3.50 4.25	10.90 13.30	14.40 17.60
80	4.00	4.00	7.62	4.80 6.10	00	5 + 6.5 +
90	4.00	4.00	8.78	4.90 6.60	00	5 + 7 +
100	4.00	4.00	10.00	5.00 7.10	00	5 + 7.5 +

**Fig. 11 B - Calculation of earthwork costs: rock**

- b) Estimating the average volume per metre depending on the mean side slope. Costs are calculated as in a);
- c) Estimating the average machine cost per metre on the basis of local empirical data.

**Table 1**

**Average production and cost of a medium bulldozer (weight 12-16 t)  
constructing a secondary forest road in the mountains of Austria**

**Machine cost per productive hour: US\$ 35-40**

	Terrain conditions		
	Simple	Medium	Difficult
Average side slope in %	30	50	70
Production in metres/hour	12 - 15	9 - 12	6 - 9
Cost per metre in US\$	2.5 - 3	3 - 4	4 - 6
Cost per $m^3$ of earthwork in US\$	1.25	1.1	0.9

Motorgraders (medium weight of 10-14 t) are employed in forest road construction mainly for battering, shaping and draining. Production is greatly influenced by the skill and experience of the operator.

In shaping the final profile and the out slope the average production is between 50 and 100 linear metres per hour. The costs are about US\$ 0.5-1 per metre.

#### 2.2.3.3 Rookdrilling and blasting

Rookdrilling in difficult terrain in Austria is performed with high-powered pneumatic drilling machines. Smaller compressor units with hand-held hammers are employed for partial or minor rookwork.

The costs for blasting depend on the type of rock and the percentage of rock in the cross-section (rock volume per m), as well as the equipment.

Average costs for drilling and blasting are now about US\$ 3.5-5 per m<sup>3</sup>.

#### 2.2.3.4 Drainage

Forest roads with a maximum grade of 10 percent are drained by means of mountain side road drains and concrete culverts. In Austria prefabricated concrete pipes are available at relatively low prices and are transported to the construction site by truck.

If such pipes are not available or too costly, culverts made from timber or concrete slabs can be constructed directly at the site. Even old barrels welded together can be used. If no suitable material for culverts is available, the mountain side road drain has to be drained by simple surface waterbars made from timber.

In areas with high annual rainfall and thunderstorms the drainage system has to be carefully planned and constructed to protect the road against erosion and destruction.

Prefabricated concrete pipes for culverts are 1 m long and have the following weights and prices in Austria:

Diameter in cm (length 1 m)	Weight in kg per m	Price on the construction site in US\$ per m
30	100	6
50	270	13
60 heavy duty	610	35
80 " "	1 000	53
100 " "	1 700	80

In Austria concrete pipes for culverts are usually laid by hydraulic excavators. The cost depends on their diameter and the type of subsoil and can be estimated on average at about US\$ 10-15 per linear metre. The well and apron for one culvert may be calculated at about US\$ 25-40.

These pipes used in forest road construction have a diameter of up to only 1 m. Specially reinforced pipes have diameters of up to 1.5 m, but these are very heavy.

A compromise between a culvert and a small bridge is a culvert of corrugated steel sheets. This material is produced in various sizes for different systems and diameters and is fitted together at the site.

Such culverts are costly, but advantageous at difficult and inaccessible construction sites. The price for culverts with diameters of 1.5-3 m is about US\$ 250-600 per linear metre.

#### 2.2.3.5 Base

The amount of base material depends on the bearing capacity of the subsoil, the width of the carriageway and the quality of the base material itself. On loamy and silty soils with low bearing capacity, expenses for the base material may be up to 60 percent of the total cost.

Base material required for a carriageway 3.50 m wide  
(empirical data for Austrian conditions)

Subsoil	clay/loam	loam/sand	sand/stone
Bearing capacity	low	medium	high
Base material (m <sup>3</sup> )	2.5 - 3	1.5 - 2	0.5 - 1

It is most important for an economic construction to find gravel deposits as close as possible to the road site, since transport costs are high. If a gravel pit or a quarry can be developed along the road to be constructed, the cost can be considerably reduced.

The base material is loaded from the deposit on to heavy dump trucks by means of a tracked loader, wheeled loader or hydraulic excavator. The average loading production is about 40-50 m<sup>3</sup> per hour under medium conditions. The cost is about US\$ 0.6-1 per m<sup>3</sup>.

The normal loading capacity of two- or three-axle dump trucks is 6-10 m<sup>3</sup> per truck. The average transport cost amounts to about US\$ 0.5-0.6 per m<sup>3</sup> and km for distances of between 10 and 20 km.

The base material is dumped on the road-bed and spread and shaped with small bulldozers or motorgraders. The costs are about US\$ 0.4 - 0.5 per m<sup>3</sup>.

Final grading and compacting of the base and surface is done with motorgrader and vibro-drum.

Machine	Production (m per hour)	Cost in US\$ per m
Grader	150 - 250	0.3 - 0.4
Vibro-drum	80 - 100	0.4 - 0.5
Total cost		0.7 - 0.9

### 2.2.3.6

Bridges, big culverts and special structures (retaining walls, timber crib revetments) are calculated individually. Planning and supervision account for 5 percent of the total cost. Unforeseen expenses should be allocated 10 percent of the total cost.

Items	Units	Price per unit	Costs
1. Preparation (felling and clearing, preblasting of stumps)			
2. Earthwork			
3. Rock blasting			
4. Drainage (culverts, water-bars, drains)			
5. Construction of the base (gravelling, grading, compacting)			
6. Structures			
7. Planning and supervision	5%		
8. Unforeseen expenses	10%		

Fig. 12 - Model of Engineer's estimate

Table 2

Summary of forest road cost in Austria

Average empirical data for easy and medium terrain in US\$ per linear metre

Road standard	Bearing capacity of subsoil		
	low	medium	high
Main road	26 - 30	17 - 19	11 - 13
Subsidiary road	23 - 26	13 - 15	8 - 10
Skidding road		1.5 - 4	

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Heavy duty tractor engaged in road formation work  
(Photo: O. Sedlak)



Tractor mounted rock-drill used in mountain forest road construction  
(Photo: E. Pestal)

MACHINE INPUT IN FOREST ROAD CONSTRUCTION WITH  
SPECIAL EMPHASIS ON ROCK BLASTING IN MOUNTAINOUS AREAS

by

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Forstabteilung,

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## 1. INTRODUCTION

Modern forest road construction by the Chamber of Agriculture started nearly 26 years ago in the province of Lower Austria, which is the largest federal province in the north-east of Austria. These roads were built mostly to serve the owners of small private forests (up to 400 ha) on hillsides and in mountainous areas. Since those times, machine input has permanently and considerably changed. In the early days of mechanized road construction in Austria, angledozers only were used. These machines were military angledozers left over from the second World War period. Austrian foresters saw the advantages of these machines for opening up the forests by mechanized road construction and developed new methods of planning, appropriate for the enormous construction capacity of these machines.

## 2. DEVELOPMENT OF FOREST ROAD CONSTRUCTION

At first, small or medium-sized angledozers (from 8 - 10 t) were used for road formation, for excavation of the gravel needed for road basing and for rough shaping. Battering, constructing culverts, digging drains, and loading basing material for the road-bed required manpower. Base material had to be moved by horse-drawn carts or farm tractors. The equipment and road construction crew consisted of an angledozer and driver, up to twenty unskilled workers, a number of carts and farm tractors and, in rocky terrain, one or two compressors operating pneumatic drills. Nowadays economic considerations require more rapid opening up of forests. With the advance into increasingly difficult terrain, lack of manual labour caused by migration to industrial zones, a high degree of mechanization in road construction methods, the share of equipment costs has now gone from about 50 percent to about 95 percent of the total road construction costs.

## 3. PRESENT SITUATION

At present different kinds of road construction equipment are used, depending on the terrain and geological factors as shown below:

### Situation A

Terrain conditions not difficult, slopes not too steep and with a low rock component:

Angledozer	16 t, 120 kw	formation, battering
Light excavator	7 t, 50 kw	roadside drains, small culverts
Grader	12 t, 100 kw	drains (V-section), shaping
Foreman or skilled worker		managing work and equipment, blasting operations
Unskilled workers:	1 - 2	drilling, assisting operators

1/ Forestry Division, Chamber of Agriculture, Lower Austria

If necessary:

Compressor, operating  
1-2 pneumatic drills;  
air output 2-2.5 m<sup>3</sup>/min;  
6 bar

0.8 t, 20 kw      minor blasting operations

Heavy excavator  
(hydraulically run)

18 t, 50 kw      big culverts, protective constructions  
consisting of large rocks.

### Situation B

Difficult terrain, steep and rocky slopes, hairpin bends required:

Heavy tractor      17 t, 110 kw      formation, battering, filling and  
depositing blasted debris

Light excavator      7 t, 50 kw      roadside drains, small culverts

Grader      12 t, 100 kw      drains (V-section), shaping

Heavy excavator  
(hydraulically run)

18 t, 50 kw      hairpin bends

Rock drill mounted on  
crawler tractor; air  
output 8.5 m<sup>3</sup>/min; 10 bar

15 t, 95 kw      major blasting operations

Foreman

managing work

Skilled worker (minelayer):      1

blasting, protective constructions

Unskilled workers :      2-3

drilling, assisting operators.

### Situation C

Conditions of terrain extremely dangerous because of slopes which are steep and formed by compact rock; damage to stands and public and private facilities must be avoided.

Heavy excavator  
(hydraulically run)

18 t, 50 kw      formation by digging "catching" trenches,  
constructing dry walls of heavy boulders  
in order to retain the spoil from the  
higher slope and/or by loading dumper-  
trucks with the surplus of material.

Rock drill (as above)

Minelayer:      1

Unskilled workers :      1-2

Dumper trucks (if necessary)      25 t, 110 kw      for longitudinal transport

Grader      12 t, 100 kw      shaping.



#### Situation D

For basing and surfacing of the forest road:

Heavy traxcavator or	17 t, 110 kw	} loading and spreading; rock and gravel
Heavy excavator (hydr.)	18 t, 50 kw	
Heavy trucks (3-axle)	25 t, 110 kw	transporting
Traxcavator	11 t, 65 kw	grading the base
Grader	10 t, 70 kw	grading the surface
Vibratory roller	9 t, 95 kw	achieving high-degree compaction of the road
Foreman		managing work.

#### 4. ESTIMATING ROAD CONSTRUCTION OUTPUT AND COSTS

For rough cost estimates, a few examples are given below:

##### Situation A

With a construction output of 80-200 m per working day (10 hours) the cost would amount to about US\$ 4 700 - US\$ 16 000 per km; averaging US\$ 6 700 per km.

##### Situation B

With a construction output of 30-80 m per working day (10 hours) the cost would amount to about US\$ 16 700 - US\$ 33 300 per km; averaging US\$ 23 300 per km.

##### Situation C

With a construction output of 50-70 m per working day (10 hours) the cost would amount to about US\$ 57 000 - US\$ 85 000 per km; averaging US\$ 70 000 per km.

##### Situation D

With a construction output of 170-250 m per working day (10 hours) the cost would amount to about US\$ 7 300 - US\$ 16 700 per km; averaging US\$ 10 700 per km.

#### 5. ROCK DRILLING AND BLASTING IN MOUNTAINOUS AREAS

After having opened up most of our forests which lie on easy terrain, we now have to make those forests which are situated in steep and rocky sites accessible by truck. In former times, between the two world wars, logs from these parts had been transported over long distances by means of horse or oxen carts, wooden sledges or wooden chutes operated by gravity.

The need to open up our protection forests is as much a part of producing timber as well as regenerating the overaged stands in these parts of the mountains. Therefore, rock blasting is becoming more and more essential.

Nevertheless, development of drilling and blasting methods is still going on and mechanised rock drilling by internal hammer with deep-hole drilling is widely practised in

in forest road construction. Today this method has some advantages over others, such as hand-operated hammer drill, external hammer drill and revolving drill. It can be applied in all kinds of rocks such as granite, limestone, dolomite and so on. This rock drill is either mounted on a crawler tractor or a wheeled tractor; the air needed (8.5 m<sup>3</sup>/min, 10 bar) for driving the hammer and blowing out is provided by a compressor also mounted on the carrier. For a 5 m wide road it is sufficient to drill one sole-hole horizontally, parallel to the direction of the road to be built on the inner side of the slope to be cut, just above the projected road-bed, provided the slope gradient of the terrain is less than 70-80%. If the slopes are greater than 70 to 80% and the road-bed is to be wider than 5 m, then more than one sole-hole may be required. Machine-mounted drills are capable of drilling 10-15 m long bore holes (80 mm in diameter).

The output of these machine-mounted drills, which are not mass produced but assembled by skilled mechanics, ranges from 5 to 30 cm/min. On the average, for placing in position, drilling, removing to a safe position and blasting, about 1½ to 2 hours are required for a single hole of 10 m.

The charge column consisting of cartridges filled with gelatine donarit (60 mm/700 mm) and plastic tubes filled with debris must be detonated by dynamite cord from the bottom of the hole; for detonating the cord an electric detonator is necessary.

No doubt, for successful and safe blasting an experienced minelayer is of the greatest value; only he will be able to set the right holes and to arrange the correct charge in order to prevent damage of the lower slope below the road.

## 6. CONCLUSIONS AND RECOMMENDATIONS

The use of traxacavators and exocavators instead of angledozers in forest road construction has proved to be of great advantage. If terrain conditions are difficult, filling and depositing of blasted debris can be done by these machines carefully enough to avoid damaging the environment below the forest roads. It should be stressed that the same forester should be responsible for the planning and supervision of forest road construction.

Forest road construction will be both economical and protective for the landscape if the crew consisting of a foreman, operators, skilled workers and the forester becomes a well trained, coordinated and experienced team.

The permanent training of this crew should be one of the main tasks of the responsible forester. High efficiency and working speed naturally may create a great temptation for the forester and his crew to disturb the landscape and seriously damage natural resources. Therefore, they should always bear in mind that road construction is no end in itself. Its purpose, on the contrary, is to support good forestry practice.

## 7. SUMMARY

Ideally, instead of one all-purpose machine, a combination of more specialized machines should be used to construct forest roads. This fact will require efficient planning, good supervision and a constantly well-trained crew.

## THE PRACTICAL APPLICATION OF SOIL TESTING METHODS ON FOREST ROADS

by

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### 1. INTRODUCTION

Forest roads, in order to serve their purpose, have to carry timber loads at the required times and the appropriate speeds.

On main roads, which may have one or two lanes, timber loads of 500-5 000 m<sup>3</sup> a year are transported at speeds of up to 40 km/h. These roads are also intended for opening up recreational woodlands. Therefore, they also serve private traffic moving at speeds of up to 60 km/h. The axle loads to be expected may be as much as 16 tons, since these roads are also used by truck, tractor-trailer units having a total weight of 38 tons.

Feeder roads have to carry wood volume loads of up to 500 m<sup>3</sup> a year at a speed of up to 20 km/h and serve only opening-up purposes. Nevertheless, they must be regarded in elaborating construction plans. Skidding roads are accessible only for cross-country vehicles, sledges, horse-drawn carts, and the like, and are used periodically.

If the local road construction material has a low-bearing capacity, reinforcing layers of screened or natural material, gravel or sand, mixed with binders (bitumen, cement) would be necessary. Feeder roads may be poorly reinforced but accessible all year round, or not reinforced and only temporarily accessible. The second type (fine-weather roads) can carry trucks only when the surface is dry or frozen.

Forest roads must be sufficiently resistant to mechanical, climatic and bacteriological influences. Appropriate construction methods and traffic safety can be guaranteed only if data are supplied by soil testing methods which help determine the quality and stability of a road. Such control data will decisively influence the excavation methods used in a certain project. There are simple procedures that permit soil testing without special devices, and laborious and complicated methods that give an exact description of soils and their qualities by reference data or curves. Most methods are standardized processes. Tests should always be carried out by experts to give reliable data.

Since there is such a large number of soil testing methods only the most important ones are mentioned in this paper, and the individual steps are not described in detail. Furthermore, only mechanical stabilization methods are described since these are most frequently used in forest road construction. Stabilization with lime, bitumen, cement, and chemical substances is of minor importance. Mechanical stabilization consists in increasing the internal friction by better distribution of soil grain sizes and compaction.

At the construction site a soil mechanics expert visually classifies the soils according to their properties. In field testing the soil is analysed and its properties described.

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However, although such a rough analysis is important it is not sufficient for an exact evaluation. Reliable data can be obtained only from mechanical tests. For an accurate evaluation of the test results it is important to know whether the test samples consisted of natural and undisturbed soil, of more or less disturbed soil, or of kneaded material. Tests are carried out either in a field laboratory at the building site, or in a normal laboratory.

## 2. ROUGH CLASSIFICATION OF SOIL PROPERTIES

Visual and manual methods serve as a rough classification.

### 2.1 Visual methods

Grain sizes, weights and percentages are estimated and colours recorded by means of visual methods.

#### (a) Soil fractions

Soil samples are picked up in the hand or spread on a suitable surface. Then the particles are compared with a reference table or objects in everyday use. The following categories are used:

- |               |   |
|---------------|---|
| Stones:       | grains bigger than a hen's egg  |
| Gravel:       | smaller than a hen's egg, bigger than the head of a match                         |
| Coarse sands: | smaller than the head of a match down to grains just visible to the eye           |
| Fine sands:   | silt and clay are not visible to the eye; therefore, manual testing is necessary. |

#### (b) Colour

The true colour of the soil can be determined only in full daylight and if freshly excavated. Changes in colour resulting from exposure to the air should be recorded. Dark colour of the soil is significant in that it indicates the presence of organic particles.

### 2.2 Manual methods

By means of simple hand and finger tests coarse and fine grain fractions as well as plasticity of the soil can be determined.

#### 2.2.1 Dry-state stability

Sun, air or oven-dried samples show varying resistance to finger pressure; this clearly indicates the dry-state stability of the soil. There is none at all if the sample crumbles at a slight touch. Dry-state stability is high if the sample can be broken only between the fingers.

#### 2.2.2 Shaking test

By means of this method the reaction of soils to shaking, particularly of silty ones, is determined.

The sample should be nut-sized and moistened. It is shaken in the hollow of the hand. When water appears on the surface the sample becomes shiny. Under finger pressure the water disappears again; with increasing pressure the sample starts to crumble. Upon further shaking the particles again cohere and the test can be repeated. The time it takes for the water to appear on the surface and to disappear under pressure is a soil property indicator.

### 2.2.3 Kneading test

By means of kneading, the plasticity of a soil and its silt and clay content can be determined.

A soft but not sticky piece of soil is rolled on a smooth surface into a bar with a diameter of 3 mm. It is then kneaded to a lump again. Rolling and kneading cause a loss of water. The soil has:

- (a) low plasticity, if a cohesive lump cannot be kneaded from the bar;
- (b) medium plasticity, if the lump crumbles under finger pressure;
- (c) high plasticity, if the lump can be kneaded without crumbling.

### 2.2.4 Rubbing test

This method serves to estimate the proportion of sand, silt and clay.

A small sample is rubbed between the fingers, sometimes under water. The proportion of sand grains can be estimated by the degree of coarseness, crunchiness and scratchiness. Clay soils feel greasy and stick to the fingers; when dry they will not come off without washing. Silty soils feel soft and floury and can be blown off when dry.

### 2.2.5 Cutting test

In this test a moist soil sample is cut with a knife; if the cut surface is shiny the clay content is high. A dull surface indicates silt or clay-sandy silt with low plasticity.

To investigate the organic elements of a soil and the degree of decomposition of organic particles it must be smelt and squeezed by an experienced tester.

## 3. EXACT TESTING

### 3.1 Determining water content

The water content determines the quality of a soil and decisively influences its characteristics such as compacting ability, its carrying capacity and resistance to frost. The water content is expressed by the weight of pore water as a proportion of the particle weight after drying at 105° C.

$$\text{Water content}_u = \frac{M_u - M_d}{M_d} \times 100$$

$M_u$  = mass of the sample undried

$M_d$  = mass of the sample kiln-dried

#### 3.1.1 Oven drying

Drying soil in an oven is the most reliable method and therefore the most frequently used. The sample is dried till its weight remains constant and then cooled down to room temperature in an exsiccator. The next step is weighing. The scales should be accurate to 0.1% of the sample weight and the maximum permissible weight difference of 0.05 grams.

Large samples cannot be weighed on precision scales and are too big for the exsiccator. Therefore, simpler scales are employed and the dry weight is determined while the sample is still warm, weighing errors being tolerated up to  $\pm 10$  grams.

The sample size chosen depends on the type of soil to be tested and should be in the 10 - 10 000 grams range for silt, coarse sand and gravels.

### 3.1.2 Calcium carbide test

Smaller samples are examined for their water content at the construction site. The accurately weighed sample is put into a steel bottle and an ampoule with a certain amount of calcium carbide, and several steel balls are added. The lid of the bottle carries a manometer. Violent shaking breaks the ampoule, the calcium carbide mixes with the soil sample thus generating an acetylene - air mixture. When the gas mixture is stable the pressure is recorded and the water content determined by means of a table. Other methods to determine water content use air pycnometers and submersion weighing. Rare methods are heating by infra-red radiation and burning of small samples.

### 3.1.3 Petrol test

This method is employed for testing coarse-grained soils such as coarse sand and sand. The fresh sample is weighed and spread in a metal basin. Then petrol is poured over the sample, and the mixture is stirred with an iron bar. The combustion heat dries up the sample; the dried sample is then weighed and on the basis of weight difference, the water content is determined.

## 3.2 Determining the state of the soil

The Atterberg soil limits which are indices for coherent soils are important control data for assessing the plasticity and compacting ability of soils. These limits indicate the points at which transitions from one state to another takes place and are expressed in percent of water content.

liquid limit  $w_f$  : transition from the liquid to the plastic state

rolling limit  $w_a$  : transition from the plastic to the semi-solid state

shrinking limit : transition from the semi-solid to the solid state

Below this limit a decrease in water content does not cause a significant change of volume.

Plasticity  $w_{fa}$  indicates the state in which the soil is kneadable. The plasticity index is expressed as a percentage and indicates the difference between liquid limit and rolling limit ( $w_{fa} = w_f - w_a$ ). The state of a soil depends on its natural water content ( $w_n$ ) and can be calculated with the aid of an index ( $k_w$ ) as follows:

$$k_w = \frac{w_f - w_n}{w_{fa}} \quad k_w - \text{states:}$$

< 0	.....	liquid
0	.....	liquid limit
0 - 0.50	...	viscous
0.50 - 0.75		soft
0.75 - 1.00		stiff
1.00	.....	rolling limit
> 1.00	.....	semi-solid/ solid

In order to find the plasticity limits of a soil the values of the liquid limit and the plasticity index are plotted into a chart as devised by A. Casagrande.

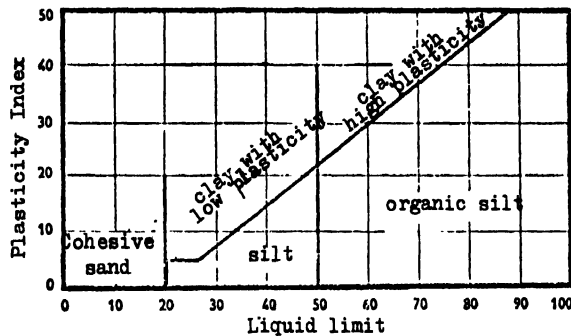


Fig. 1 - Plasticity chart

From the calculated values and the graphic representation the plasticity of the soil type can be examined and its compacting ability easily determined. In practice the liquid limit is found by means of a method devised by Casagrande. Samples with grain sizes of  $< 0.4$  mm and varying moisture contents are filled into cups. Then a small furrow is drawn in the samples. The cups are hung in a device operated by a handle, which is turned. The cups strike the ground till the furrow closes. The number of strikes and water content are entered on a record sheet. The resulting four to six values are combined and the water content after 25 strikes is expressed as a percentage.

The samples are rolled on a water-absorbent surface to a thickness of 3 mm (rolling limit). The process is repeated till the sample starts to crumble, and the water content of the particles is determined.

### 3.3 Determining grain size composition

The grain size is calculated by the diameter of a sphere which can pass through the same sieve as the grains and has the same sedimentation speed in water. The value for grain distribution indicates the proportion of various grain sizes existing in a particular soil. Grain distribution is graphically represented by a curve.

This mechanical analysis is used for determining the composition of a natural soil or base material. The sample is put through a series of screens and thus fractionated.

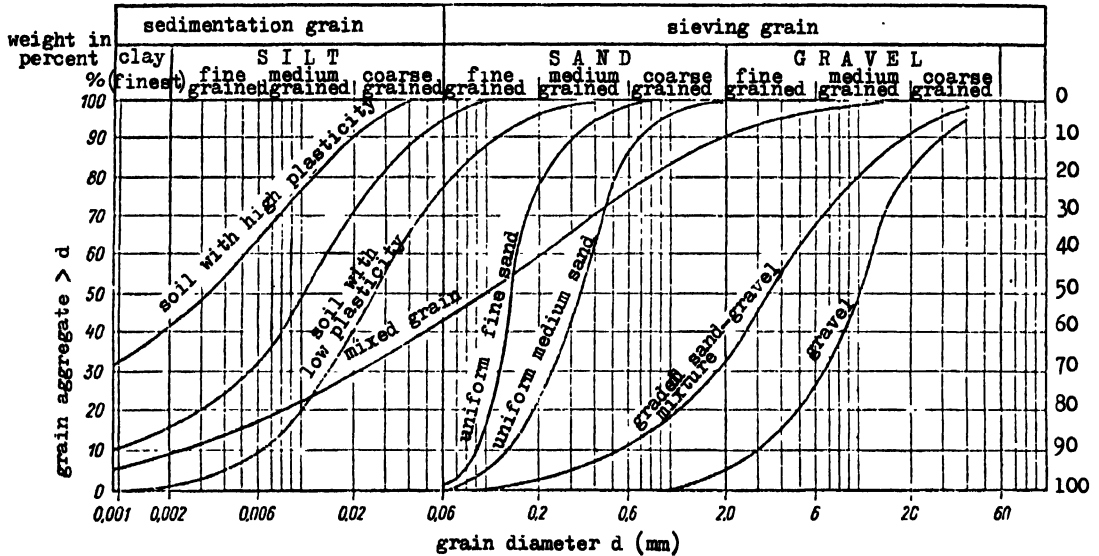


Fig. 2 - Characteristic grain distribution curves

There are two main groups:

- (a) Sedimentation grains with clay particles of  $< 0.002$  mm and silt with a diameter of  $0.002 - 0.06$  mm. Grain size and distribution are determined by analysis of water sedimentation.
- (b) Sieving grains with a sand grain size of  $0.06 - 2.0$  mm and a gravel grain size of  $2.0 - 60$  mm. Grain size and distribution are determined by dry sieving.

A mixed grain structure contains sieving grain and sedimentation grain sizes. Examinations are carried out by sieving to a grain size of  $0.063$  mm and subsequently analysing the sedimentation. In a soil mixture the grains should be distributed in such a way that the spaces between the large grains are filled with fine grains; there should be as few void spaces as possible. The grain distribution curve of favourable road material is represented by a quadratic parabola. If  $p$  is the percentage of material falling through the sieve with the mesh size  $d$ , and if  $d_0$  is the smallest grain and  $D$  the largest one, the equation reads as follows:

$$\frac{d^m}{D^m} = \frac{p}{100}$$



The parabolic exponent for useful mixtures is  $0.40 < m < 0.55$ .

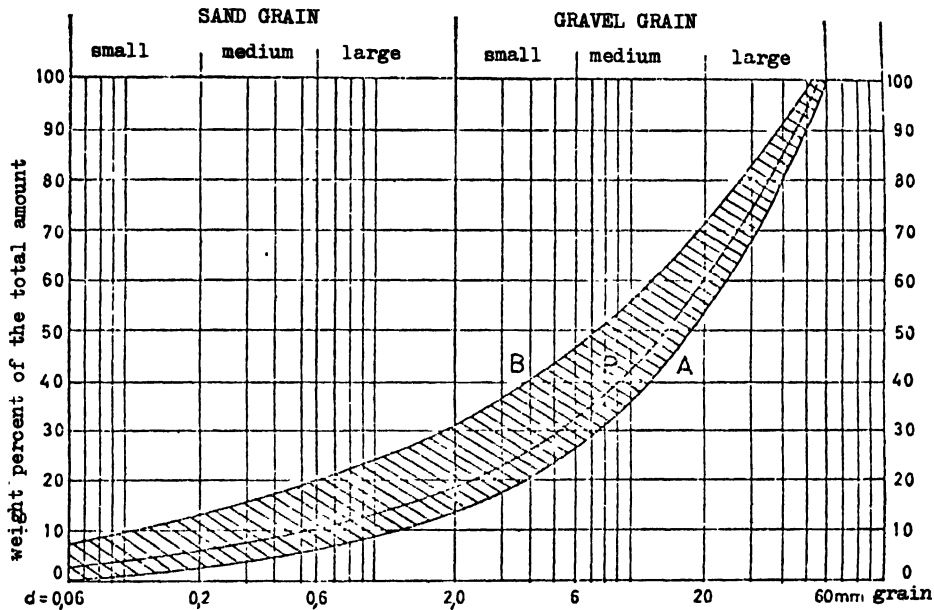


Fig. 3 - Grain distribution curve of a broken mineral mixture  
A, B marginal sieve lines  
P quadratic parabola

### 3.4 Determining the Proctor density

Cohesive and non-cohesive soils have an optimum density. This can be determined in the laboratory by means of the Proctor test and is called simple (100 percent) Proctor compaction. This is the compaction a soil type can reach when its moisture content is most favourable for construction, and is called the dry volume weight. In this context a differentiation is made between soils that are difficult or easy to compact. In the first group are all cohesive soil types, uniformly grained non-cohesive or slightly cohesive soils with a non-uniformity of  $U = 1.5 - 3$ , and light and heavy rock. Soils that are easy to compact are well-graded sands or sand and gravel mixtures, and non-cohesive or slightly cohesive soils with  $U = > 7.0$ . Non-cohesive or slightly cohesive soils with  $U = 3 - 7$  require intensive compaction.

The standard of non-uniformity is  $U = \frac{d_{60}}{d_{10}}$ . In this formula  $d_{60}$  and  $d_{10}$  are the

grain sizes that correspond to the ordinates 60 percent and 10 percent of the grain distribution curve. Soils with  $U \leq 5$  are called uniform and soils with  $U > 5$  are called non-uniform.

### Test description

To an air-dried sample having a grain size  $< 7$  mm, water is added until the water content is approximately 5-6% below the estimated optimum water percentage. The thoroughly mixed material is introduced into a standardized cylinder in 3 layers. Each layer is compacted by 25 strokes (gravity weight). Both the cylinder and the compacted sample are dried. Then the dry volume weight is determined. A small quantity of material is extracted from the centre of the sample and its water content determined. The same process is repeated for samples with 2-3% higher water contents, until the moist volume weight decreases. All the values are then plotted into a chart and the resulting curve is the Proctor curve. The dry volume weight at the top of the curve is the highest value that can be achieved under the given test conditions. The volume of the compacted soil sample must always be recorded in order to find the dry weight difference between the construction site sample and the laboratory sample with a Proctor density of 100 percent. If the latter has a dry volume weight of  $1.80 \text{ g/cm}^3$  and the former  $1.71 \text{ g/cm}^3$  this means that a Proctor density of 95 percent was achieved.

If during compaction only 90 percent of the Proctor density is achieved, settlement of the road material after construction is to be expected under traffic conditions. It is therefore important to check the water content of soil with a certain grain distribution during excavation by means of the Proctor test. There must be optimum moisture content to guarantee good compaction.

### 3.5 Determining deformation

The plate-bearing test is employed when other compaction tests cannot be applied, as for example in the case of large rubble hills.

The plate bearing test serves to find the degree of deformation ( $E_v$ ) or the bedding index ( $k$ ) of the non-bituminous, non-cement bound base of gravelled roads. Furthermore, it indicates compacting ability, load capacity and density of a soil. It is applied in all cases in which other compaction tests fail, that is for coarse-grained, stony and rocky material.

Since the plate bearing test can be carried out only at the construction site and costs in time, equipment and material are high, it is only rarely used in the construction of forest roads.

More important than the above-described method is the CBR test (California bearing ratio) which is used extensively in non-European countries. This test is an empirical method for determining the relative bearing capacity of the sub-soil. The method, which was developed in the USA, is standardized. The deformation resistance of a soil which was first compacted in the laboratory is determined by means of an indenter. Deformation resistance is defined as the compaction a soil must have to allow indentation of  $1.25 \text{ mm/min}$ .

The compaction of the sample is compared with a standard sample (graded, crushed rock) compacted under the same conditions and over the same indenter path. The compaction ratio between the samples is expressed in percent. CBR-values in the range of 15-40%, 40-100% indicate good, and values between 70-100% excellent soil characteristics.

### 3.6 Determination of water capillarity

It is important to know the capillary height of sands and fine gravels if they are to be used as frost protection material. The capillary height must lie below the frost protection layer. In general, a soil is sensitive to frost if it has a degree of non-uniformity of  $U < 5$  and more than 10 percent of grains under  $0.02 \text{ mm}$ , or if the values are  $U \geq 15$  and more than 3 percent of the grains are under  $0.02 \text{ mm}$ . During the freezing process such a soil draws water into the frost area (groundwater, drainage water) which is deposited in layers of ice. When they thaw, the soil becomes saturated and soft and loses its load-bearing capacity.

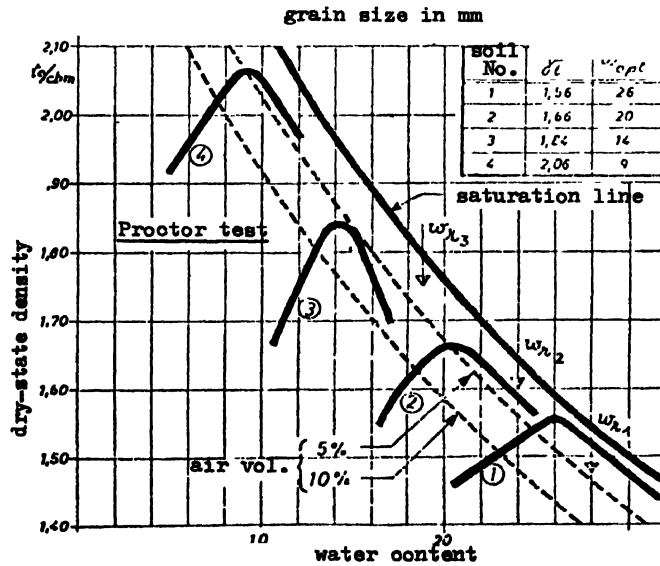
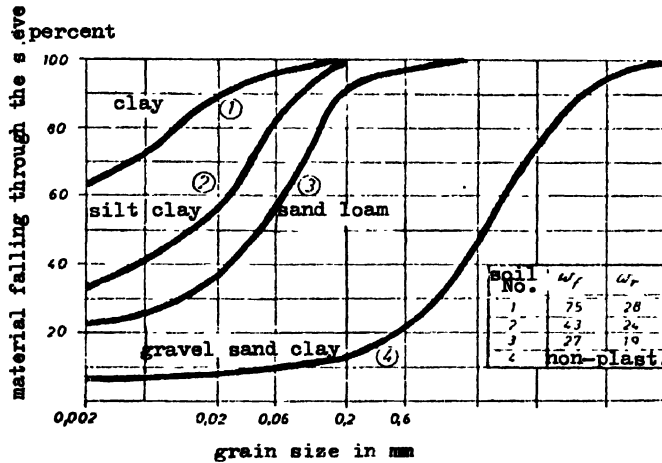


Fig. 4 - Compaction curve for different soil types

A soil exposed to frost can be protected by the addition of material with a grain size of  $> 0.02$  mm. Addition of individual big stones is not very useful; a good grading of the sieve curve is more important.

The simplest device to determine capillary height up to 1 m is the so-called ascending tube, a calibrated cylinder of glass or clear plastic with a finely meshed lower edge. The soil is oven-dried, filled into the cylinder and compressed with a wooden pestle. The cylinder is then put into a container of water and the capillary limit (indicated by a change in colour of the soil from light to dark) can be read. The sample size depends on the size of the cylinder and ranges from 4 - 15 kg. The diameter of the largest grain should not exceed a fifth of the diameter of the cylinder.

#### 4. EXTRACTION AND TREATMENT OF SAMPLES

Test samples have to be extracted at points which are representative of the average particle distribution in nature. To examine the soil types in an existing road, samples are extracted from all its layers. The number of samples to be sent to the laboratory depends mainly on the diameter of the largest grain (as indicated for some methods), individual samples are combined to give a good representative sample for determining the soil type.

The individual samples are blended, thoroughly mixed, heaped and divided until the required test quantity is obtained.

The consistency of cohesive soils may need to be determined. In this case the samples have to be kept in vacuum containers till they are tested. To test the density of a sample - in order, for example, to determine compaction - individual samples instead of a mixture are used. These are taken with special tools in order not to disturb the sample. The extraction data should be carefully entered on a record sheet.



Participants listening to the lecture on soil tests (Photo: T. Pasoa)

## ROAD EMBANKMENT STABILIZATION WITH BIOLOGICAL AND ENGINEERING WORKS FOR FOREST ROADS

by  
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### 1. INTRODUCTION

The basic requirements for modern forest management, especially wood harvesting, are well planned and designed forest road networks. Careful attention has to be paid when planning and locating roads, especially in steep terrain, to avoid or minimize the erosional impact of roads on the environment.

Areas particularly susceptible to erosion problems such as very steep slopes with easily erodable soils and rock strata dipping towards the slope should be avoided as much as possible.

Erosion caused by road construction and soil disturbance can be avoided by using biological means and/or engineering structures. Slope and gully erosion adjacent to the road is very often a result of over-grazing and denudation of hills which expose the soil to wind and rain and endanger the road structure. Erosion often occurs on the cuts and embankments as well as on the outlets of cross drains, water flows and on the surface of the road itself.

This paper describes briefly how to plan and survey forest roads efficiently to meet technical standards, keeping soil disturbance to a minimum by fills and cuts, in order to make the least possible erosional impact when constructing forest roads.

Revegetation practices are presented in detail to demonstrate how mass slope failures can be controlled. Simple and inexpensive types of engineering structures are also presented.

### 2. ROAD PLANNING, SURVEYING AND DESIGN

To plan a road alignment, good topographical maps, preferably with a scale not larger than 1:10 000, are necessary. The main points to be opened up by the forest road should be determined and marked on the map. If no good contour maps are available, then extensive field work is required to measure all main points barometrically and to record detailed terrain features. For low-cost roads such as forest roads, the survey method differs significantly from the classical engineering surveying methods. In a reconnaissance survey the main points which have first been marked on the map should be traced in the field, height measurements should be taken and recorded. The survey of the road itself consists of taking measurements in between the polygon points determined by the geometrical requirements of the road, which are dependent on the standard of the roads. Distances, vertical and horizontal angles are measured at each point by means of tape measure, clinometer and hand compass. It is advisable to measure the road line back and forth in order to have a control measurement and to exclude errors in measurement readings. This simple surveying method has proved to be very efficient and sufficiently accurate for low-cost roads.

Especially in steep and difficult terrain it is a great advantage to use this simple surveying method, as it would be quite costly and time-consuming to survey with a theodolite. When surveying forest roads it should be borne in mind that road excavation volumes and fills should be balanced, thereby achieving minimum soil disturbance. On slopes steeper than 70 percent it is advisable to construct full bench roads. It may often be necessary to construct retaining walls made of rock masonry, logs or gabions to further reduce cut and fill soil disturbances, especially on steep and unstable slopes.

On such slopes, mid-slope locations of roads should be avoided. In general, road gradients should not be more than 10 percent. Only in exceptional cases, and over short distances, 12 percent may be acceptable. In areas with high precipitation, water run-off on soil surfaces is considerable and on roads with steep gradients precautionary measures with adequate drainage facilities are required, such as pitched ditches, open top culverts, frequent and sufficiently wide culverts, fords and bridges.

In addition, under certain conditions it is advisable to slope the road surface about 3 percent towards the downhill slope. This is best applied on full bench construction roads. Outward sloping of the road surface has the advantage that precipitation of road surface water drains off laterally, therefore the quantity of water accumulated in cross drains, open top culverts and sub-base culverts will be less, and risk of erosion reduced. However, outward sloping should not be applied on clayey road surfaces as they become extremely slippery when wet, and where slope falls occur, especially if they are not protected by vegetative cover.

On inward sloping roads, the road surface water drains off towards the slope, where a mountainside ditch, preferably paved, drains off the water to culverts which bring the water to the downhill side of the road.

Culverts should be protected by head walls; they should be sufficient in number to prevent the water causing erosion problems in the ditches as well as in the area below the culvert outlet. They should be placed safely in the road sub-base. (The compacted layer above the culvert should be equal to the diameter of the culvert, but at least 50 cm in order that they are not destroyed by traffic).

Depending on the amount of debris material, normally 30-60 cm diameter precast concrete culverts give satisfactory results. If larger diameter culverts are required, corrugated steel culverts should be used; they are easily transported and set up at the construction site - but they are more expensive. Another way to avoid larger diameter cross culverts would be to install two parallel pipes, forming a culvert.

The gradient of the piped culvert should not be less than 3 percent and not more than 6 percent because low and/or quick running water has a negative effect on the protective structures of culverts.

Special attention should be paid to the surfacing of the road. A favourable soil mixture to be used as carriage way and surfacing material should consist of sieving grain <sup>1/</sup> and sedimentation grain sizes, so that there are as few spaces as possible between the large grains.

### 3. SLOPE PROTECTION AND STABILIZATION

First of all it is most important to determine the source of factors influencing slope instability in order to be able to design appropriate control and rehabilitation measures. Very often a single measure may achieve the desired results but sometimes it may be necessary to combine measures to restore the stability of the slopes. For instance, on a seepage

<sup>1/</sup> Sieve grain sizes are from 0.06 to 60 mm.

slope it may be only necessary to drain off the water with open ditches or stone-filled drains. On other occasions, it may, however, also be necessary to revegetate the slope in order to fix the slope surface because vegetation would not come back at all or it would take too long a time, and a retaining wall would be required. In a mountain road project in the USA (Idaho) it was noted that 80 percent of the surface erosion occurred within one year on the disturbed slopes; thus it is important to stabilize slopes shortly after construction of a road.

### 3.1 Slope drainage

The simplest method to safely drain off springs and surface water is by means of an open ditch or a system of open ditches. The main ditch is located in the direction of the slope gradient; secondary or lateral ditches are located in a fishbone pattern. Water should be collected as closely as possible from where it originates and be channelled safely to the road ditch, culvert or any other nearby water course. In areas with steep gradients and a large amount of water run-off, pitched ditches may be required. The excavation of the ditches should start at their lowest point so that the accumulating water may drain off immediately. A very effective method of draining off sub-surface water is by means of so-called "covered drains". On cut slopes these drains may also act as a type of retaining structure if made in a "Y" or arch shape, thus further increasing slope stability. The most common types are stone or gravel filled drains with or without pipes.

To check the efficiency of drains and for maintenance purposes, it is advisable to have a standing pipe at the junction of the main and secondary drains. Pipes may be made of concrete, brick or PVC material. The excavation of the drains should start at the lowest point, the laying of pipes should be started at the top. The pipes should be placed as tightly as possible to each other, and they should be laid in water-tight soils so that maximum water drainage can be achieved. Piped drains are the most efficient and their effectiveness is long-lasting; however, they are more expensive and often not available. Normal stone drains may silt up after some time therefore it is advisable to form a drainage channel of stones at the bottom of the drains, or to put in a bundle of brush wood at the bottom of the drain. The top of the drain may be covered with a layer of grass in order to more effectively prevent the siltation of the drain.

Besides using them effectively to stabilize fill and cut slopes, drains may be very useful behind retaining walls.

### 3.2 Revegetation of road embankment and slopes

Well-known revegetation measures for stabilization of cut and fill slopes may be grouped as follows:

- i) Seeding, grass turving and mulching to obtain a grass cover;
- ii) Contour wattling, wicker work fencing, contour planting and fascines to obtain shrub vegetation;
- iii) Reforestation with pioneer plants.

#### 3.2.1 Seeding

Very often before sowing grass seeds on barren slopes, soil and site preparation such as shaping the slope, spreading humus and application of fertilizer may be required. The seeds may be either sown on the entire area, in rows or in certain places only. To seed an area of 100 m<sup>2</sup>, about 3 kg grass seeds will be needed. It is an advantage to have legume seeds mixed with grass seeds as they are especially nitrogen fixers. It will take 1/2 - 1 working hour to seed 100 m<sup>2</sup>. A mixture of deep-rooted and flat-rooted strong, quick-growing pioneer grasses will give the best results in fixing the soil.

1/ Poly-Vinyl Chloride

### 3.2.2 Grass turfing

To regenerate vegetation through placement of grass sods, it must be borne in mind that grass sods need to be placed on the slope when the surface is wet and during the vegetative period. Depending on the availability of grass sods, slopes may be entirely covered by them or only in strips. The latter application would require additional seeding. On very steep slopes fixation of the grass sods may be necessary in order that they get a firm grip on the surface. This can be done by means of sticks prepared from branches, twigs, or bamboo.

### 3.2.3

Mulching is a very quick method of regaining grass cover on sterile, bare soils. This method of revegetation requires a layer of straw, wood fibre or other organic material which is spread on the soil. Seeds and fertilizers are added and finally the layer of mulching is fixed by spraying a cold asphalt suspension. The advantage of mulching is that the grass cover comes up after a relatively short time because a favourable microclimate and conditions are created; it reduces water loss from soil, surface temperature and soil crust formation as well as preventing seeds from rolling or being washed down the hill, and it also preserves the fertilizer. In the USA and Japan machines (hydro-seeders) have been developed which can spray the mixture of mulching material mixed with water and an adhesive as well as seeds and fertilizer on to the slope in one operation.

In Middle-Europe in the alpine region, revegetation by mulching techniques has been successfully used with the following method of application: the slope is covered by a layer of straw (2-4 tons/ha), which is spread by hand, by utilizing a ladder which is placed on the slope. Seeding and fertilizing are carried out by spreading seeds and fertilizer by hand, again utilizing ladders. Seeds and fertilizer fall through the straw layer onto the soil. For the fixation of the straw layer on to the slope surface, an asphalt suspension of 50 percent asphalt in water, is watered to a 25 percent solution which is applied on to the straw by means of a portable rucksack-type sprayer. About 0.5 litre of asphalt suspension per m<sup>2</sup> is applied. Spraying cannot be carried out during heavy rain and wind. Normally it takes 2 to 3 hours after spraying before the mulching is fixed in position. In general by the time the asphalt suspension covering the straw layer has disintegrated the grass vegetation is well established.

### 3.2.4 Contour wattling

Contour wattling, also called "wattling and staking", is one method of achieving a brush vegetation on steep slopes where a grass cover would not be strong enough to stabilize the soil. The idea is to subdivide the slope with dense brush rows and, if necessary, grass seeding can be applied between the rows to obtain additional soil fixation. Before starting with the wattling and staking, slope preparatory work should be carried out, such as levelling of small gullies or removing such obstacles as big loose boulders and branches. Then stakes should be driven in along the contours at certain distances from each other within the contour line as well as from row to row. It is desirable to have every fourth stake as a sproutable stake. Staking should be started from the lowest part of the slope, moving uphill. Trenches should be dug just above the stakes and wattling consisting of sproutable twigs and branches be put in the trench, overlapping each other. Part of the twigs and branches should be above the surface to prevent soil from moving down the slope. The soil dug out is used to cover the lower contour wattling. Some technical data are given below, as well as production data of an example of contour wattling carried out in Jamaica under the supervision of Mr. Sheng, FAO Watershed Management Officer. Stakes sharpened at the bottom, 1 - 1.2 m long and with a diameter of about 5 cm with a row interval of 1.2 m and 0.50 m from each other were driven into the soil, leaving about 15 cm of the stake above the soil surface. Thus a hectare would require about 17 000 stakes. Contour trenches 20 cm wide and 25 cm deep were dug and bundles of wattling 13 cm in diameter and 3 m long laid<sup>2</sup> in the trench. A ten-man crew may be able to complete contour wattling work on up to 250 m<sup>2</sup> per day. Within the working crew, six labourers staked two trenched and covered wattles, and two labourers were used for transporting and other duties.



Another example where several species to be used as cuttings were tested by Mr. Tautsocher, FAO, was in Nepal. Those found to be most suitable for cuttings were Salix tetrasperma, Salix vallisbiana and Viburnum.

### 3.2.5 Wicker work fencing

The system is similar to the one mentioned above and is widely used in the alpine region in Middle Europe. The difference is that the sproutable material is not put in bundles into the soil, but is put around the stakes like a fence and the ends of the sproutable twigs are put into the soil.

The rows must not necessarily follow the contour lines; very good results have been achieved with rows placed at an angle of 45° forming rhomb shapes with 1.5 - 4 m long sides. The stakes are driven into the soil with a spacing of 40-50 cm, having a length of 1-2 m and diameters of 5-10 cm. The stakes should be driven into the soil three-quarters to two-thirds of their length. The spacing of the wattle rows very much depends on the gradient of the slope and soil. Normally they are 1-4 m apart, laid out in parallel rows. In alpine regions good results have been achieved using Salix spp. and Alnus spp. as sproutable fencing material.

### 3.2.6 Contour planting (cordons)

Sproutable plant material of 0.9 to 1.5 m length is placed in horizontal cross layers into the contour terraces. Terrace digging starts from the bottom of the slope proceeding to the top. The lower cross layers of sprouting material are covered with soil obtained from the excavation of the upper terrace. The spacing of the terraces depends on the gradient and the soil; it may be up to 3 m. The width of the terrace should be 0.5 - 0.6 m. Cordon layers may either follow the contour in a continuous line or be broken say to 5 m, and their ends overlap each other as the cordons progress up the hill. With the indicated spacing of contour planted rows, 3 500 to 5 000 cordons per hectare would be required for the rehabilitation of the eroded slopes.

### 3.2.7 Fascines

The technique is similar to the one used in contour planting. It differs in that instead of putting cross layers in the contour terraces, brushwood is laid in. This can be mixed with cuttings to achieve a green brush row. Shoots are put between the brush rows or seedlings are planted. Terraces should have a gradient of 20 to 25 percent towards the slope having a width of 0.6 - 1.2 m. The brushwood and cuttings should be about 20 cm longer than the width of the terrace.

### 3.2.8 Reforestation

Revegetation work should be carried out with pioneer plants to stabilize slopes subject to landslides, or as a preventive erosion control measure on severely degraded slopes. In alpine regions pioneer plants such as Alnus, Betula, Fraxinus and Prunus have proven to be most successful as far as their survival rate on eroded slopes is concerned. When considering plants for use as slope stabilizers it should be borne in mind that they must have strong, deep roots to bind as much soil as possible. Wherever possible it would be desirable to select species for afforestation on bare slopes which could be used as fodder or fuelwood trees, since there is a desperate need for such trees in many developing countries.

## 4. STABILIZATION OF DRAINAGE WAYS

Unprotected drainages which cross roads are very often the source of major erosion problems. Erosion mainly occurs on unprotected outlets of the drainage where runoff water frequently develops gullies through its erosive force, which in some cases can cause landslides and damage to the road structure. Protection of water drainage outlets and channels

can best be done by pitching the soil surface with dry stones or cement-bonded stones. In channels with steep gradients, it is advisable to have some stones cemented along the channels which are above the bed of the cement stone channel, thus reducing water velocity and its destructive erosion forces.

A cheaper way of stabilizing channels and outlets of water crossings is to provide rock rip rap which in many cases gives satisfactory results.

For the protection of bridges, culverts and fords, structures such as rock rip rap, dry stone or cement stone retaining walls, or where applicable, wooden protection structures may suffice. Very often revegetative treatment on the slopes of cross-water drainage ways gives satisfactory protection.

## 5. SLOPE PROTECTION WITH ENGINEERING STRUCTURES

Simple engineering works for forest road construction such as dry stone structures, gabions, log crib revetments, timber retaining walls, etc., have proved very useful in many countries. They are inexpensive and easily constructed at the required sites using local material. As cement is often difficult to get or is not available in remote areas of developing countries, transport costs are high and skilled masonry labourers scarce. In this paper the main emphasis has been put on dry stone structures and timber construction works.

### 5.1 Stone arches

Stones are placed in the form of arches into the soil of cut slopes. The width of such arches may be 0.60 to 1.20 m and they may be up to 1 m in depth. In between the arches and above them, cuttings of Salix spp. may be planted to achieve additional stabilization.

### 5.2 Dry stone retaining walls

Stones, 20 to 30 cm in size, are placed next to each other into the surface of the slope. For the setting of stones into the soil surface 2.5 - 4 m<sup>2</sup> per man/day may be achieved and in addition, provisions for obtaining and transporting the stones will have to be made.

### 5.3 Gabions

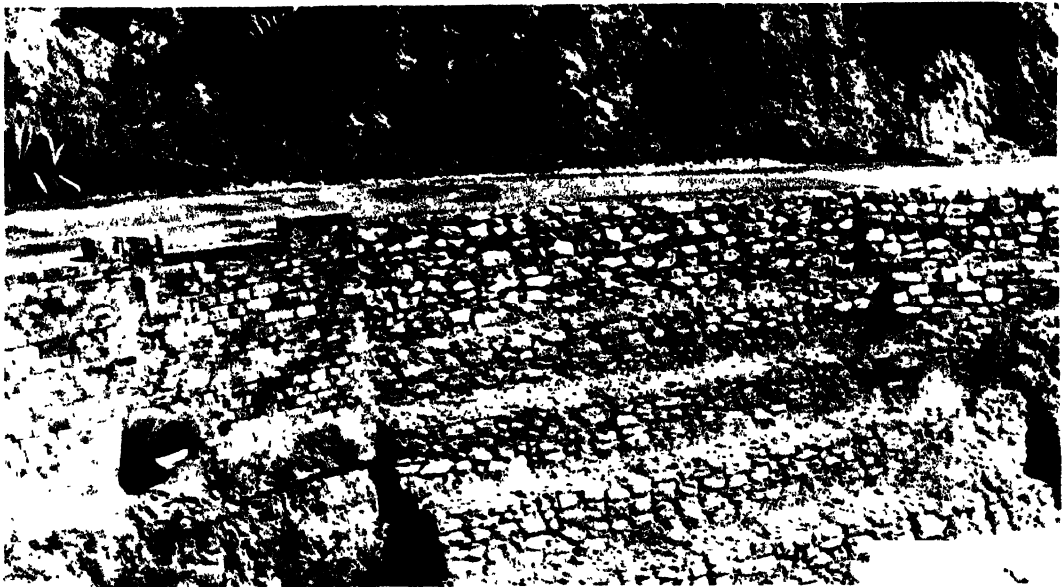
Gabions are structures made of stones which are normally set up by hand labour and covered with wire mesh to keep them together.

The advantages of gabions are:

- i) their construction is simple; with proper supervision, unskilled labourers can set up these structures;
- ii) they are cheap;
- iii) stone material which is available in many places at the construction site can be used;
- iv) only wire mesh or wire needs to be purchased and transported to the construction site;
- v) their construction time is short;
- vi) they are very durable; in comparison to cement masonry walls, they are more resistant against mass movement without breaking, because they are flexible;
- vii) water drains off easily, thus increasing the shear strength of the soil and reducing the erosion hazard of the slope to be protected;
- viii) in between the stones grass grows sooner or later, thus making the gabions even more stable and integrating them into the environment.



Construction of a retaining wall consisting of rock boulders placed into the cut slope by excavator (Photo: O. Sedlak)



Destroyed retaining wall efficiently replaced by gabion (Photo: R. Heinrich)

Based on information collected in Nepal the costs per m<sup>3</sup> of gabion constructed amounted to some 140 Rupees or US\$ 11.24.

Basic data used in the cost estimate are as follows:

Labour wages (average)	= 12 Rupees per working day
Income of foreman	= 500 Rupees per month

Average construction output per m<sup>3</sup> of gabion = 1.9 man days, which includes preparation of wire mesh, collecting stones near the construction site, transport and setting up the stones, forming the construction, as well as rock fill.

Cost of wire per m <sup>3</sup> of gabion, including transport and tax	= 110 Rupees
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Direct cost per m<sup>3</sup> of gabion (in Rupees)

• Labour (1.9 man days)	22.8
Supervision	4.0
Hand tools	2.0
Wire	110.0
Total	138.8

#### 5.4 Log crib revetments

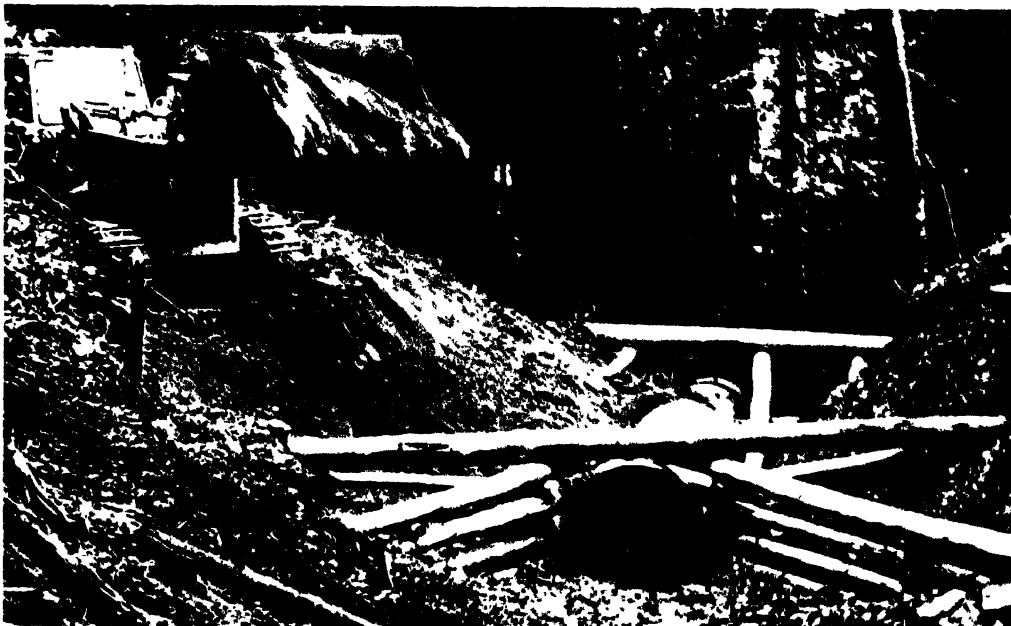
These structures may be of use where wood is easily available and where there is no adequate stone material or where the construction costs of stone structures are excessively high because of long transport distances of the stones. Log crib revetments are made of roundwood, consisting of logs laid parallel to the slope and crosslayers, which fix the structures into the subsoil of the slope. The crosslayers should be put at a spacing of 1 - 2 m. In between the log layers, placed parallel to the road, stone fill and additional sproutable material may be placed, protecting the road from stone and earth material. Log layers and the ends of the cross logs must be fixed either by spikes or notched to fit into each other. In severely sliding areas, it is advisable to construct log crib revetments consisting of front, back and cross layers of logs, which would form a cage (crib) and would thus be more resistant to the gravity force of the slope material. The advantage of log crib revetments are that they can be set up in a short time, they are cheap, local tree species can be used and they are more resistant to slope movements than inflexible masonry constructions. Their disadvantage is that they have a limited life, generally 10 - 15 years; however, by that time it is expected that treated slopes will have been stabilized.

#### 5.5 Timber retaining walls

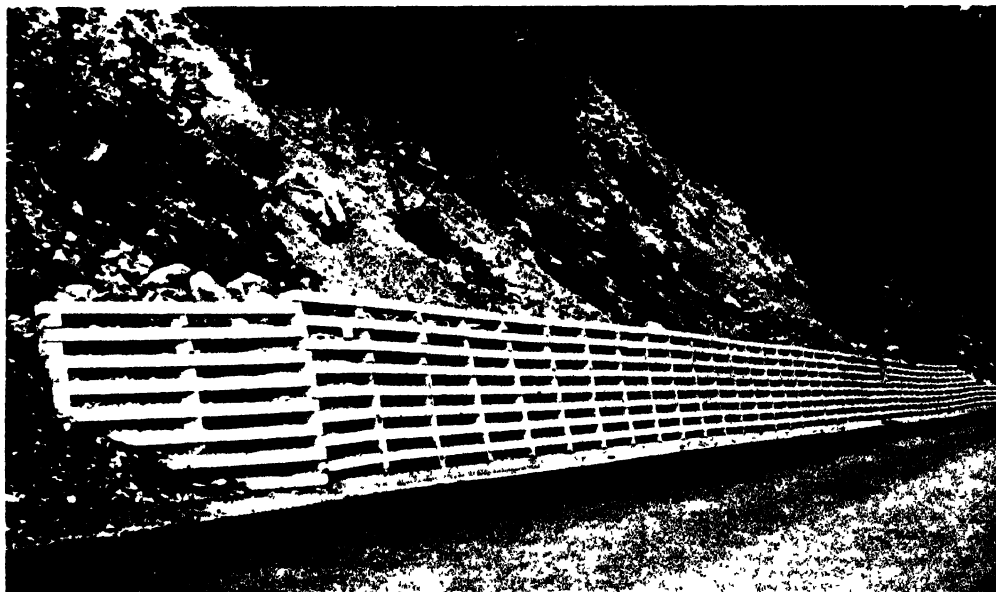
This simple type of structure may be built to protect slopes from erosion. Stakes are driven into the subsurface of the slope and timber is nailed onto them on the upper side. They are placed near the road and if necessary higher up on the slope along the contour lines of the cut slope.

#### 5.6 Precast concrete crib revetment

These structures have been developed for areas where neither stone nor timber is economically available. Concrete beams of 250 cm x 12.5 cm x 12.5 cm weighing about 90 kg and crossbeams of 125 cm x 12.5 cm x 12.5 cm weighing about 45 kg are used for this type of structure. This example is only mentioned to give a more complete picture of the development in this sector of construction. At present their application may not be economically feasible in many developing countries, except for locations close to a source of cement.



A gully being filled by traxcavator, concrete culvert and supporting roundwood construction laid so as to guarantee natural waterflow (Photo: FAO)



Concrete crib revetment consisting of precast concrete beams (Photo: E. Pestal)

## 6. PROTECTION OF ROAD EMBANKMENTS AGAINST TORRENTIAL WATERFLOWS

Damage to roads caused by torrential waterflows may occur when the roads are located along or across the torrents. Erosion caused by the running force of water may endanger or destroy the banks or embankments of roads or the road itself by its scouring effect and erosion of the toe of torrent banks. At crossings of torrents or gullies, the road may become blocked by sedimentary material or destroyed by downhill mass movements. Necessary rehabilitation measures in controlling erosion caused by torrents are to reduce the velocity of water by engineering structures and rehabilitating slopes of the gully or torrent banks. Thus, a combination of biological and structural bank stabilization, as well as putting in check dams, or sills and check dams, may be required in order to fully protect the road from erosion and sedimentation caused by torrential waterflows.

### 6.1 Embankments

Embankments may be constructed with different materials. The most common type is made of rocks. Stones protecting the toe and bottom of the channel should have a diameter of at least 0.5 m and those protecting the banks should be of 0.3 m and above. If only smaller stones are available, paving with stones covered by a wire mesh is very effective.

A very quick method of stabilizing embankments is by putting boulders on the banks of the torrents - these structures are called "rip rap". In torrential flows with great hazards of bed erosion and scouring, the paved toe may be protected additionally by placing boulders on it.

A combination of layers of boulders and layers of fascines with sproutable material may give very good results, as the water velocity is reduced by the fascines on one side and the embankments are made more stable because of the vegetative cover. The cuttings should be driven about two-thirds of their length into the subsoil.

Boulders in combination with grass turfing, or grass turfing and planting of brush and trees on the embankments, may provide good results in stabilizing embankments.

In areas where wood is available, log crib revetments with stone fill between the logs may be constructed. At the bottom of the timber crib revetment a layer of logs should be placed in order to prevent the fill material from being washed out of the structure.

Bank revetments and training walls made of concrete are very effective - however, they are more costly than the structures mentioned above.

## 7. ROAD SURFACE PROTECTION

### 7.1 Open top culverts

An effective way to control road surface erosion is to put in open top culverts or simply earth cross-drains, which will lead the surface water from the road. Open top culverts can be made of steel, concrete, timber, roundwood, or simply earth debris. Open top culverts must be placed into the road with a cross-gradient in order that they will be self-cleaning. Normally a cross-gradient of 6 - 7% is sufficient.

The effectiveness of open top culverts depends very much on the correct spacing and maintenance work (clearing of soil particles, leaves and twigs, etc.) in order to keep them functioning effectively. The spacing of open top culverts depends mainly on the gradient of the road, amount of precipitation, steepness of terrain and soil conditions. In a watershed forest in steep terrain with high rainfall, Sessions (1974) proposed an open top culvert spacing in metres derived by the formula 800 divided by the gradient in percent. However, in areas with heavy rainfall and large catchment areas, a closer spacing (20 - 40 m), especially on roads with gradients of 9% or higher, may be required. The correct spacing

of open top culverts may be worked out through experience. The table below can be used as a guide.

<u>Spacing of open top culverts in metres</u>		
<u>Road gradient</u> <u>in percent</u>	<u>800</u> <u>gradient in ‰</u>	<u>Suggested spacing in steep</u> <u>terrain with heavy rainfall</u>
5	160	30
6	130	65
7	114	55
8	100	45
9	88	40
10	80	35
11	72	30
12	65	20 to 30

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**Motorgrader putting in a crushed rock base layer  
(Photo: Federal Forestry Research Institute)**



THE INFLUENCE OF FOREST ROADS ON RUN-OFF DEVELOPMENT  
OF SEDIMENTATION AND LANDSLIDES

by

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1. INTRODUCTION

Natural conditions in mountainous regions are dominated by hydrological and geomorphological phenomena and processes, chiefly heavy floods, erosion, mass movements (landslides, slips, movement of debris, mudflows) and sedimentation. Zones which are especially characterized by these processes are torrents and unstable slopes. These are the two features which cause most of the problems to a roadbuilder in the mountains.

The construction of a forest road creates a two-way effect: firstly, run-off, erosion, landslides and movement of debris can destroy the forest road or interrupt traffic; and secondly, the forest road can intensify erosion, change the stability of slopes, cause landslides and increase sedimentation (Figure 1).

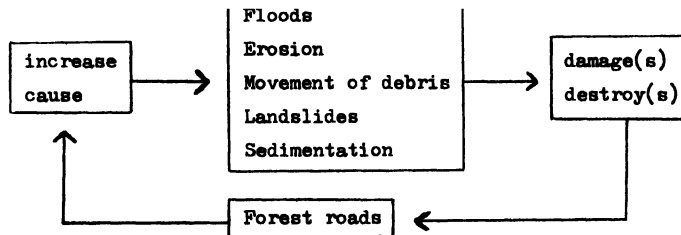


Fig. 1 - Possible mutual effects of natural phenomena on forest roads

Therefore, the design of a forest road in the mountains has to include: a) measures which prevent or alleviate the damage or destruction caused to the road by torrents and unstable slopes; b) precautions against causing or increasing effects (erosion, movement of debris and sedimentation) or landslides by construction of the road. Without these precautions the construction of forest roads often endangers or devastates areas and buildings below.

Experience and investigations have shown that the most important ecological effects of the construction of forest roads are as follows:

- a. disturbance of the run-off on slopes and in channels
- b. destruction of the vegetation cover
- c. erosion

<sup>1/</sup> Federal Ministry of Agriculture and Forestry, Vienna

- d. production of landslides, movements of debris and mudflows
- e. sedimentation

These effects are caused by the artificial removal or transposition of masses of soil and the resultant change of the morphology of slopes and channels.

## 2. RUN-OFF

In a simplified model of the run-off process(Figure 2) we can distinguish the following phases:

- a. precipitation
- b. depression storage
- c. surface run-off
- d. infiltration
- e. interflow
- f. percolation
- g. channel run-off

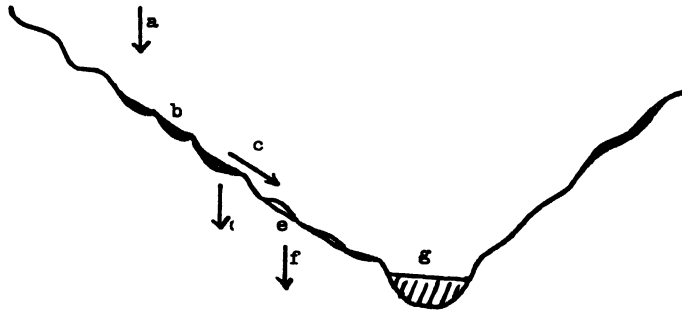


Fig. 2 - Principal phases of the run-off process

An increase of run-off influences or produces other processes, for instance erosion, landslides, movement of debris and sedimentation, and so can cause damage and destruction.

The most frequent causes for disturbance of run-off as a result of road construction are the following:

- a. concentration of the surface run-off and interflow by cutting the slope (gully erosion) or the production of debris movement or landslides caused by the increase of infiltration into the down-hill slope;
- b. reduction of the cross-section of the channel. This often occurs when material is deposited on the bed of the channel or side walls are constructed;

- c. building of culverts and bridges. When a forest road cuts across a channel, it is necessary to construct an Irish bridge (Ford), a culvert or a bridge. If the diameter of the culvert or the span of the bridge is too small to let floods or branches, tree-trunks and other debris pass, these constructions have an effect like a check-dam or a barrier. In such cases, the floods flow over the culvert or the bridge and the road in the immediate area, causing damage and/or destruction.

In steep torrents these man-made barriers sometimes break, causing effects like those of bursting dams.

### 3. EROSION

Erosion depends on a wide range of factors: intensity of precipitation, run-off, the substratum and inclination of slopes or channels.

On a slope the following different kinds of erosion (fluvial erosion) can be distinguished:

- a. sheet erosion, where the soil is removed in a thin layer or sheet;
- b. rill erosion, where the concentrated water cuts rills in the surface which before was relatively smooth;
- c. gully erosion, where soil is removed by excessive concentration of running water which forms deep channels or gullies.

A distinction may be made between bed and bank erosion in a channel when the running water causes deepening of the channel bed and cuts off the banks.

How does erosion begin? Running water tries to destroy the structure or the cover of the soil impeding it and to remove the particles which form the soil or its cover. The force developed by the water is called "tractive force". The material of the soil or its cover has a certain resistance to destruction and removal because of the coherence and weight of its particles. To put it simply we can say that: erosion occurs when the tractive force is stronger than the resistance of the soil. Therefore, two general possibilities exist to reduce or prevent erosion:

- a. to reduce the tractive force of the water;
- b. to strengthen the resistance of the soil.

The construction of a forest road intensifies erosion because of the following factors:

- a. destruction of the vegetative cover which offers much greater resistance to erosion than bare soil. Most of this destruction is caused by the deposition of material during the road construction;
- b. concentration of surface and channel run-off.

The following figures show the increase of erosion because of forest road construction in mountainous regions in the USA with a precipitation of 1 500 mm per year:

Period	Rate of erosion (eroded material)
Before construction of the forest road-net	20 - 30 kg/ha/year
After construction of a road-net of 40 m/ha	2 000 - 4 000 kg/ha/year
After grass-growing	100 - 150 kg/ha/year

#### 4. LANDSLIDES

A landslide (landslip, slump) is a downward and extended movement of the soil mass of a slope which collapses and works loose from the stable mass. The stability of a slope depends on the coherence of the soil particles, expressed by the term "shear strength" ( $T$ ). With a simplified model the interaction of different determining factors which can cause and accelerate landslides or alternatively stabilize a slope can be seen in the following four figures (Figures 3A, B, C and D).

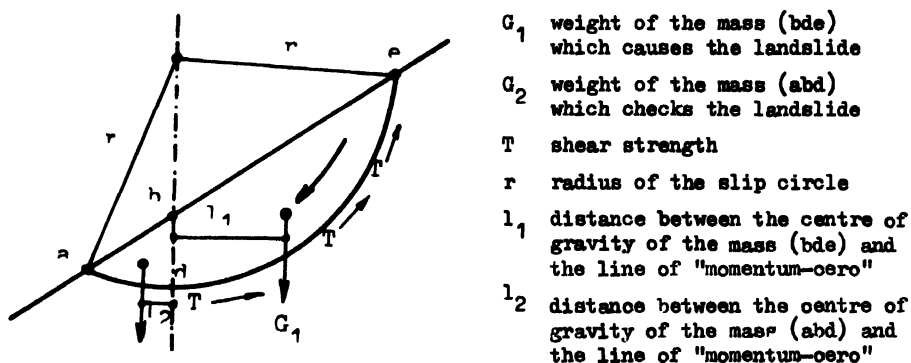


Fig. 3A - Model of the principal forces in a landslide (Cross-section)

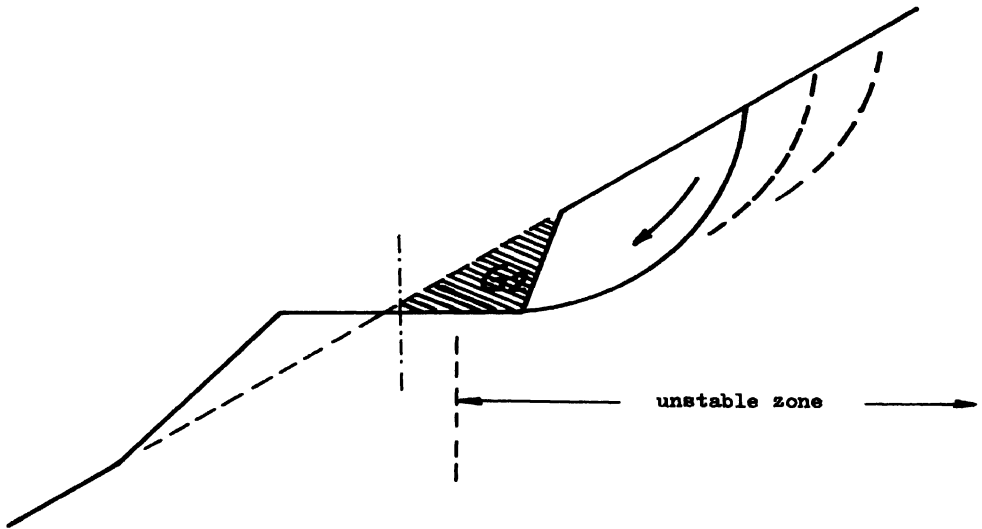


Fig. 3B - Cutting the slope reduces the soil mass which checks the landslide ( $G_2$ )

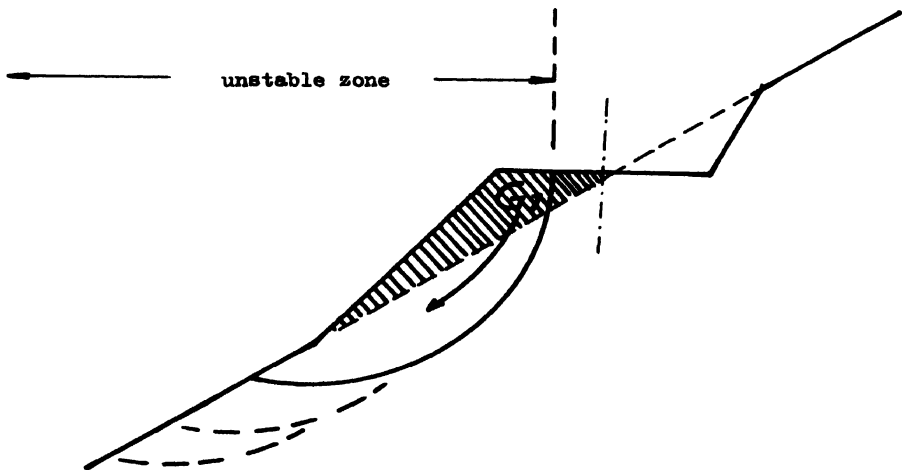


Fig. 3C - Additional load increases the weight of soil mass ( $G_1$ ) which causes the landslide

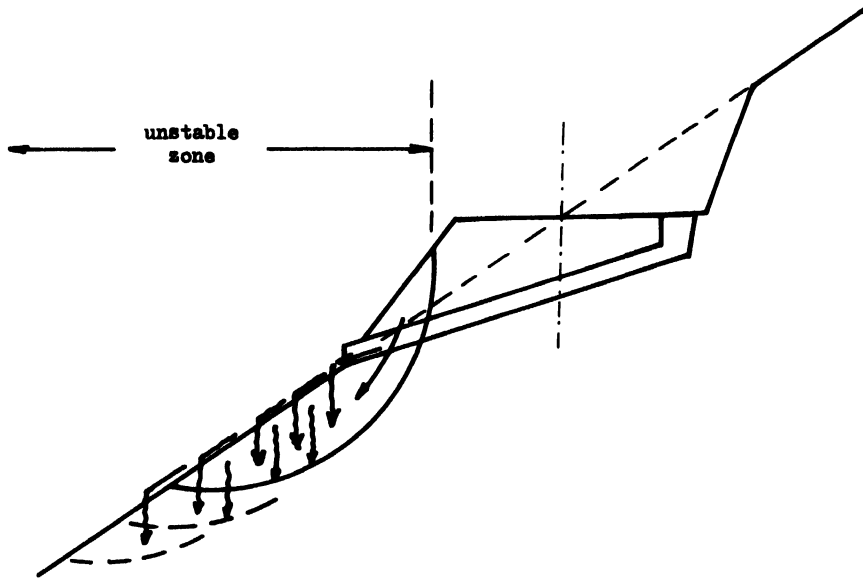


Fig. 3D - Excessive infiltration of water reduces the shear strength

On a slope consisting of homogeneous and coherent material, the longitudinal section of the mass movement is bounded by a curve which may be seen as part of a circle. With reference to the rules of statics, we can say that a slope is stable under the following conditions:

$$G_2 \cdot l_2 + T \cdot r \cdot \alpha > G$$

$G_1$  = weight of the mass which causes the landslide

$G_2$  = weight of the mass which checks the landslide

$T$  = shear strength

The stabilizing factors are therefore  $G_2$  and  $T$ .

In connection with forest roads, a landslide can be caused by the following processes:

- a. reducing  $G_2$ . This can occur when the slope is undercut by road construction;
- b. increasing  $G_2$ . This can occur by overloading with deposited material, for instance, in constructing the fill;
- c. reducing  $T$ . This can happen through infiltration and percolation caused by inadequate surface drainage.

The occurrence of mass movement, chiefly landslides, in connection with forest road construction is not limited to steep or naturally unstable slopes; other factors also have a great influence. This is shown by the table on slope stability classification developed by T.C. Sheng (1966).

Table 1 SLOPE STABILITY CLASSIFICATION

Factor	A 4 points	B 3 points	C 2 points	D 1 point
1. Site	Site does not belong to B,C or D	High ridge	Along road	Along stream or reservoir
2. Slope	< 20%	> 46%	20% - 25%	26% - 45%
3. Presence of slides	None	Few	Some	Many
4. Soils	Medium texture	Coarse texture	Medium stony	Fine texture or coarse stony
5. Land use or cover	Dense cover	Sparse cover	Cultivation without conservation	Use with severe soil disturbance

Stability class: 20 - 18 points: stable  
 17 - 12 points: relatively stable  
 11 - 10 points: unstable  
 9 - 5 points: highly unstable

## 5. SEDIMENTATION

The causes of sedimentation are erosion, landslides, movements of debris and mudflows. Sedimentation in channels reduces the cross-section and causes floods and inundation with all their resultant damage and devastation. Sedimentation reduces the capacity of reservoirs.

"Reservoirs are meant to store water, not sediment. Sediment stored is at the expense of this year's water - both quantity and quality; and it is at the expense of water supply, flood control, and water-based recreation in future years" (Anderson, H.W., 1974).

Investigations show an intimate relation between road construction in mountain areas and sedimentation. Roads which create the greatest effect of sedimentation are those alongside streams, which increase sediment deposits by as much as 6.9 times.

## 6. RECOMMENDATIONS

A systematic and careful design is necessary in order to avoid devastation, damage and destruction caused by erosion and mass movement in connection with forest road construction. It should include precautionary and protective measures.

The most important precautionary measures are the following:

1. Fill-slopes, slope-retaining walls and side-walls should be constructed and situated outside of channels; and the material resulting from slope cutting should be deposited outside channels. In this way the roadbuilder avoids dangerous reduction of the cross-section of the channel and the possibility that deposited material in the channel becomes eroded or that erosion of the opposite bank or the bed of the channel occurs. If depositing material or siting structures (retaining walls or side-walls) in the channel are inevitable, protective measures are necessary to avoid the damage and destruction that may result.
2. The roadbuilder must design and construct an adequate system of road surface drainage which takes into account the hydrological conditions existing in this area. (For more details see references 2 and 7). Special attention must be paid to the maintenance of this system and to the protection of the slope downhill from the outlets of the culverts.

Very often this point of water concentration is the cause of gully erosion and landslides, especially on slopes with finely textured soil. The protective structures required (rip rapping, lined ditches or paved channels) depend on the water discharge and their purposes: to resist the tractive force of the water and/or to reduce the concentrated infiltration of water into the slope. Investigations show that improved drainage with stabilization of the road surface can reduce erosion and sedimentation by 44 percent.

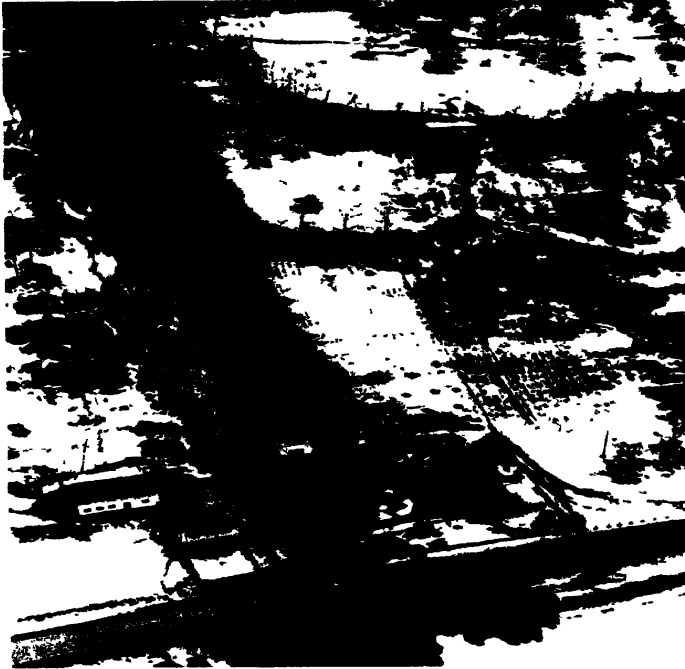
3. The most frequent inroads on the stability of steep and unstable slopes are made on the one hand by cutting the slopes (so reducing the mass which stabilizes) and on the other hand by fills (so increasing the weight of the possible landslide mass). To compensate for these effects, the roadbuilder can either construct retaining walls to support the batter and/or introduce a slope drainage system to increase the shear strength and so the stability of the slope. But these engineering measures are usually very expensive. In most cases the roadbuilder tries to avoid such unstable zones by designing another route for the forest road.
4. The diameter of culverts and the span of bridges must be large enough to ensure that floods and the mass of bed load (in torrent channels) can pass. It is frequently useful to construct a ford instead of a culvert or a bridge when a forest road crosses a steep torrent channel.
5. To make the least erosive impact when constructing a forest road, it is essential to carry out revegetation of the cuts and fills as well as the bare areas caused by depositing soil material. Revegetation of the cut slope is especially important in the case of inward sloping roads in order to avoid sedimentation of the upper side drains which causes inundations and the resultant severe erosion of the surface of the forest road and the fill slopes. (More details of biological means are given in reference 7).

Protective measures are described in detail in references 5, 6 and 7.



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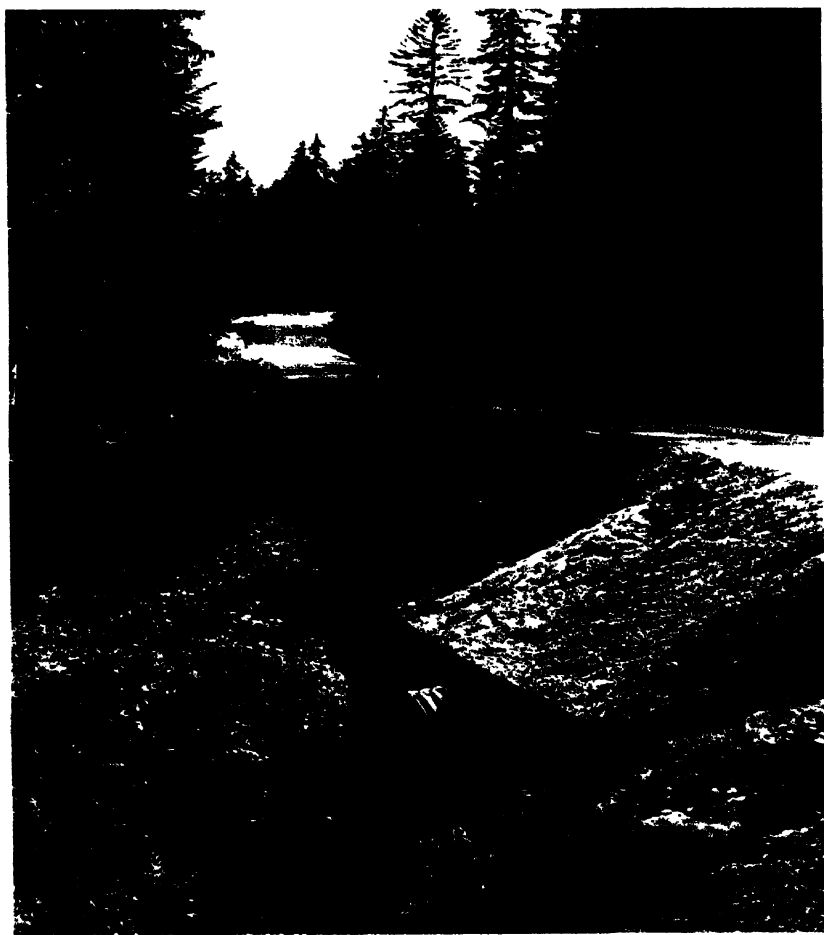
A road which has been incorrectly designed and built is the cause of mudflow devastation of downhill areas and buildings (Photo: Wildbach-u. Lawinenverbauung, Kärnten)



The total lack of a road surface drainage system has led to landslide and gully erosion (Photo: Wildbach-u. Lawinenverbauung, Kärnten)



Inadequate fill construction (additional load on the downhill slope) and an inadequate road surface drainage system have caused landslide and gully erosion (Photos: Wildbach- u. Lawinenverbauung, Kärnten)



Forest road with mountainside road ditch showing well protected outlet  
of corrugated steel sheet culvert (Photo: R. Heinrich)

**TORRENT ENGINEERING WORKS FOR THE PROTECTION OF MOUNTAIN  
FOREST ROADS IN THE REGION "SALZKAMMERGUT", AUSTRIA**

by  
**Manfred Jedlitschka**  
Sektion Wildbach- u. Lawinenverbauung Gmunden 1/

**1. GEOGRAPHICAL LOCATION, GEOLOGY, CLIMATE, VEGETATION**

The Salzammergut is the most southern region of Upper Austria, three quarters <sup>2/</sup> of the area being situated in the northern limestone Alps, one quarter in the flysh zone <sup>3/</sup>.

The region extends between the 13th and the 14th degree of eastern longitude and between the 47th and the 48th degree of northern latitude. The N-S oriented Traun valley lies at an altitude of approximately 450 m above sea level; the highest elevations of the mountain range are made up of the following geological formations: Triassic and Jurassic limestone and dolomite <sup>4/</sup>, which reach an altitude of 3 000 m above sea level.

From the climatic point of view, Salzammergut is situated in the cool moderate annual temperature range, with moderately warm summers and moderately cool winters with heavy snowfalls. The average annual temperature is + 8.0°C, extreme values are - 24.3 and + 35.6°C. The annual precipitation ranges from 1 700 to 2 300 mm depending on the altitude, of which about 350 mm fall as snow. The annual evaporation ranges from 335 to 590 mm, again depending on the altitude. The maximum daily recorded rainfall to date was 255 mm. Vegetation consists of hardwood/softwood mixed forests (beech, spruce, fir) in the valleys, and of sub-boreal softwood forests (spruce, pine, larch) at the higher altitudes.

The geological formation has an essential influence upon forest road construction as well as on torrent control works. On limestone and dolomite there are only shallow weathered soils, the slopes are steep and make road construction expensive, since extensive rock blasting is required.

The gradients of channel bottoms <sup>4/</sup> of torrents in limestone and dolomite are very steep and generally contain a great deal of debris material. The flysh zone, with its high clay content, is geomechanically very mobile and tends to slip, drift, and soil creep occurs frequently after heavy rainfalls. The stability of such slopes is often disturbed by road construction, where sidehill cuts may often lead to landslides. The torrents have deepened in the relatively soft bedrock, thus creating steep, often unstable river banks. As a consequence of the tight and hardly water permeable clayey formation, rains are rapidly discharged over the surface and the torrents swell tremendously, especially during periods of heavy rainfall.

**2. HISTORY OF TORRENT CONTROL AND FOREST ROAD CONSTRUCTION IN THE "SALZKAMMERGUT"**

The development of torrent control protection works in the Salzammergut is closely related to the history of salt mining. In salt mining tremendous quantities of timber were needed, which were transported by water (floating).

1/ Department of Torrent and Avalanche Engineering Works, Gmunden.

2/ A geological formation in Austria, composed of successive layers of shale and sandstone which can be found in the Alps.

3/ The name of a limestone found in the Alpine regions of Austria and Northern Italy.

4/ Also often referred to as TALNEG.

From the 14th century, in order to make optimum use of water as a means of transporting timber and thus to facilitate floating, waterways were permanently maintained and generally wooden stream bank-protective structures were built, where and when required. These structures had a secondary beneficial effect, namely that of protecting the nearby populated areas from floods and mudflows. As the salt factories began using coal instead of timber for firing, timber gradually lost its importance as fuel and thus the floating of wood decreased and from the middle of the 19th century the first structures for floating began to decay and disintegrate.

The disintegration of these man-made protective structures soon allowed heavy water damage to commence on the unprotected river beds and banks, which was followed by land devastation after torrential rainfalls. These latter pointed out the necessity of protective measures on mountain streams. The government institution "Torrent and Avalanche Engineering Department" was created in Austria in 1884.

With the increased use of heavy earthmoving machinery after World War II, the amount of road construction developed enormously, thus posing many new tasks for the Department of Torrent and Avalanche Engineering. On the one hand, road construction itself required protective measures against the dangerous effects of erosion and increased waterflows from torrents. On the other hand, road construction very often changed the character of the waterways by discharging road surface water and debris material into them which, in turn, frequently called for expensive protective measures on the downstream waterways.

### 3. EXAMPLES OF TYPICAL CONTACT FIELDS BETWEEN FOREST ROAD BUILDING AND TORRENT CONTROL

#### 3.1 A 6km long forest road (valley road) needs to be protected against the erosional effects of the water of the torrent: Langbathbach, in the commune of Ebensee.

Technical data: catchment area  $37.7 \text{ km}^2$ , valley length 12 km, altitude range of 430 m to 1 850 m, talweg gradient 1.3 to 5.0 percent, dolomite and limestone, maximum flood discharge  $190 \text{ m}^3/\text{sec}$ .

In 1897 and 1899, four days of rain (376.8 mm in 1897, 505.4 mm in 1899) caused flood disasters which devastated one quarter of the commune of Ebensee. The wooden structures which had been built for floating and which were already in bad condition, were, to a large extent, destroyed and several kilometres of forest road were destroyed completely, four bridges collapsed and the river bed deepened up to 4 m, 14 dwelling houses were completely destroyed and 22 were damaged.



Flood disaster of 1899 in the valley Langbathbach, Ebensee (Photo: M. Jedlitschka)

Protective measures: Torrent engineering, whose objectives were two-fold, was called for. These objectives were: total protection of the endangered commune of Ebensee and the reconstruction of 6 km of the completely destroyed forest road. To protect the commune of Ebensee against floods and mudflows, a 400 m long paved canal was established, in which the maximum 100 years' flood as well as the resultant torrent bed load could be transported. The reconstruction of the forest road required the lifting of the heavily eroded river bed by some metres, in order to create a wide valley bottom, in which both river bed and forest road could be side by side.



Protective measures in the same area as shown in the previous photo  
(Photo: M. Jedlitschka)

The river bed was lifted up to 5 m by means of 49 paved check dams and with this a solid base against erosion, with a new talweg position, was created. As a second step, the road embankment was reconstructed, for the protection of which 6 200 running metres of cyclopean <sup>1/</sup> masonry and dry stone masonry walls were established. Also, on the opposite side of the river where there was no road, the toe of the slope was stabilized by means of 5 850 m of retaining walls and rip rap. The eroded slopes were stabilized by means of 6 400 m of contour plantings using 78 000 willow cuttings. Effluent sediments were reduced considerably by systematically erecting small retaining structures (check dams) in the steep tributaries.

At a cost of 1.2 million "Friedenskronen"<sup>2/</sup>, the Langbathbach was systematically provided with protective structures, which after 80 years are still functioning fully and have

During the 6-year construction period, up to 1 000 workmen were employed. The first three photographs show the disaster caused by the torrent and the reconstruction and, finally, the stabilization effect of erosion control measures for one and the same stretch of the river.

<sup>1/</sup> Large rocks and stones

<sup>2/</sup> Currency in use in 1900 in the Austrian-Hungarian Empire



Road and watercourse stabilized by torrent engineering works in the same area as shown in the two previous photos (Photo: M. Jedlitschka)

3.2 The forest road crossing the torrent Klausgraben in the commune of Ebensee, on its scree 1/cone.

Technical data: catchment area  $0.3 \text{ km}^2$ , valley length 1 km, altitudes ranging from 650 to 1 800 m, talweg gradient 13 to 33 percent, limestone and dolomite, maximum flood discharge 6 m<sup>3</sup>/sec.

Klausgraben creek contains water only after heavy precipitation and remains dry most of the time. With the occurrence of torrential rains, the creek water carries a great deal of debris, which is deposited at the alluvial fan, thus devastating bottom farmland. In 1955, a mudflow destroyed the forest road and damaged the farm buildings of the former imperial hunting castle and its surroundings.

Protective measures: The objective of carrying out torrent engineering constructions was to protect the forest road, buildings, and farmland. In order to achieve this, a series of check dams made of concrete cemented stones and roundwood were constructed over the entire length of the torrent scree cone.

The check dams gave the water course the required direction and a solid base against channel erosion. The waterfalls at the dams considerably decreased the energy of the running water and, between the dams, a gradient was formed which levelled out with the interplay of the tractive force of the water and the inertia force of the sediments. In the area of the forest road and further downstream near the river mouth, over a distance of 200 m, the torrent was guided through a paved channel. In this section, any sediment material is to be transported by the water and any deposition of gravel and undesirable floating wood is to be prevented by means of protection work which is particularly important in front of and under the bridge. The running water is concentrated in the paved channel and the tractive force of the water increased. In the natural channel the river bed would be too rough and part of the water would be lost by seepage. In order to save money, a mistake is often made of regulating the torrent only in the immediate vicinity of the bridge rather than at the top of the scree cone from where the water can be safely led to the bridge. As a result of improper placing of structures, the torrent breaks out above the bridge, finds a new channel and endangers or destroys the forest road and/or bridge.

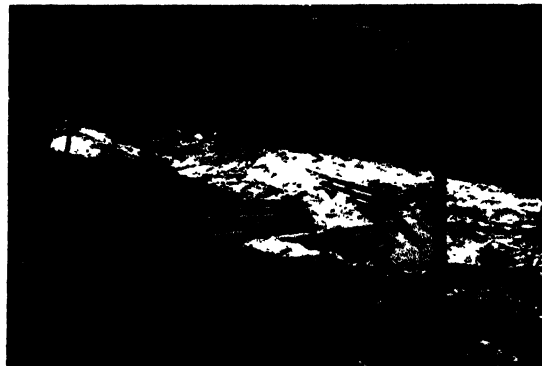
1/ The debris deposited from a steep gorge into a valley.



These protection works were carried out in 1967 and 1968 using 12 men. Construction costs amounted to 1.4 million Austrian Schilling 1/.



An alluvial fan has been stepped by a series of check dams, made of stones, well adapted to the landscape (Photo: M. Jedlitschka)



A series of check dams made of roundwood at the top of a scree cone (Photo: M. Jedlitschka)

1/ 1 US\$ was then worth about 26 Austrian Schilling.

### 3.3 Adverse influence of forest road construction upon the torrential waterway Schubach, Commune of Bbensee.

Technical data: catchment area 0.7 km<sup>2</sup>, valley length 1.5 km, altitude range from 450 to 1 200 m above sea level, talweg gradient 20 to 55 percent, rocky sub-soil of limestone and dolomite, maximum flood discharge 14 m<sup>3</sup>/sec.

The Schubach is a very steep torrent, which has partly deepened down to the bedrock. It has water only after sudden rainstorms and showers. In the course of forest road construction, the entire blasted material was deposited on the very steep, forested downhill slopes.



Blasted material deposited on a steep slope  
(Photo: M. Jedlitschka)

After a heavy thunderstorm in 1977, the slope surface water run-off transported the blasted rock material into the river bed which was then suddenly carried downstream as a mudflow. As a consequence, the bridge at the main road was blocked, the torrent overflowed onto the road and deposited part of its load, which impeded traffic.

Protective measures: Part of the blasted material was still being deposited after the torrential rainfall of 1977 and this lay in the river bed ready for removal by one means or another. In order to avoid the costly removal of this mass of material, two sedimentation check dams made of concrete were built, one of which is periodically emptied by means of a front-end loader. The retention value of the dam, with a capacity of 1 000 m<sup>3</sup>, is thus kept constantly ready to retain sedimentary material which may be carried downstream after heavy rains. The two dams were constructed in 1977 with 8 workmen. Construction costs amounted to 1.9 million Austrian Schilling.

Overall economic considerations: The length of the forest road crossing the catchment area of the Schubach is approximately 800 m. From this short section the excavated soil and rock material were deposited on the downhill slopes of the road, without properly controlling their placement, which finally required protection works amounting to 1.9 million Austrian Schilling.

These expenses could have been avoided if careful road construction technology had been carried out, i.e. the use of less explosives (smaller charges), so that the blasted rock would

have remained in situ instead of rolling down the slope. The rock excavation material could then have been loaded onto trucks and deposited in safe places, where it could not roll down into the torrent.

Additional costs for this transportation of the excavation material for a section of 800 m would have amounted to a maximum of 30 percent of the measures required for torrent control works. From the viewpoint of economy, it is therefore necessary that the road builder be fully responsible for the consequences of road construction and liable for any damage.



Concrete sedimentation check dam  
(Photo: M. Jedlitschka)

#### 3.4 Protection of the forest road against the river bank cutting into the flysh zone (slippage zone), Dammbach, Commune of Altmünster.

Technical data: catchment area  $2.5 \text{ km}^2$ , valley length 4 km, altitudinal range from 450 to 800 m, talweg gradient 2 to 20 percent, maximum flood discharge 25.0 m<sup>3</sup>/sec., the sub-soil composed of flysh sandstone and clayey marl.

The rocky sub-soil weathers very easily, the weathered stratum is therefore very thick and very fertile soils are formed. Because of the high clay content, water runs off very quickly, torrents swell rapidly and there is a great danger of landslides. The weathered stratum and the rocky sub-soil show little resistance to water action (bank erosion). Torrents erode particularly in their outside curves causing slips at the slopes close to the banks and thus endangering and/or destroying adjacent forest roads.

In the flatter downstream areas (1-4 percent gradient) of the waterways, the valleys are mostly wide enough to provide plenty of space for both the torrent and the road. Here the banks are protected against bank erosion with hand-placed rip rap and the river bed is secured against erosion by means of wooden bed sills.

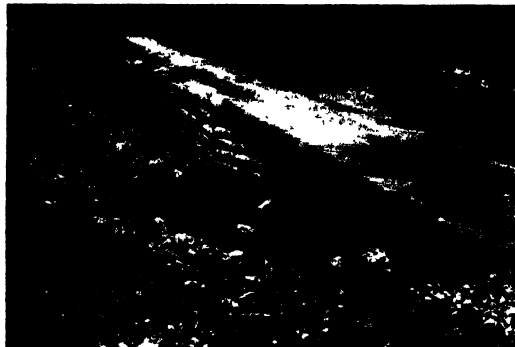
The steep initial parts of the torrents of the flysh zone are mostly deeply cut into a V-shape and therefore there is little space left for the road. Here it is necessary to construct an almost vertical timber crib revetment replacing the natural bank, in order to gain space for the road. To avoid scouring of the timber crib revetment, a base in the

form of wood sills is built into the stream bed. These sills are indispensable beneath bridge abutments.

For bridge construction in the unstable sub-soil, the following method has proved to be successful: the river bed is considerably lifted by means of a check dam and the abutments are erected immediately upstream. In this way, one saves on height of the abutments as well as on the span of the bridge and, at the same time, the check dam protects the abutments against scouring.



Bank protection with hand-placed rip rap and wooden bed sills  
(Photo: M. Jedlitschka)



Vertical timber crib revetment replacing a natural bank  
(Photo: M. Jedlitschka)

### 3.5 Multiple protective effects of sediment dosing dams; Gimbach, Commune of Ebensee

Technical data: catchment area 26.5 km<sup>2</sup>, valley length 8 km, altitude ranging from 500 to 2 400 m, talweg gradient from 2 to 6 percent, maximum flood discharge 74 m<sup>3</sup>/sec., limestone and dolomite.

Today, settlements have penetrated so far into the Alpine valleys that it is no longer merely the forest roads which need protection, but also houses, settlements, industries, power plants, railways and highways, many of which have been built on the alluvial cones of the torrents and are thus threatened by disaster.

In order to protect these valuable objects and installations, simple stream regulation works no longer generally suffice, therefore special engineering constructions are needed to avoid the potentially destructive forces of the torrent. By means of special check dams <sup>1/</sup>, sediment impacts or mudflows are prevented from advancing to the infrastructure, but are checked and deposited in the retention area of the dam. At times of mean waterflow, the deposited sediment seeps slowly through the slots of the dam and is thereby removed without causing damage.



Example of a sediment flushing dam  
(Photo: M. Jedlitschka)

<sup>1/</sup> Self-flushing dams

#### 4. CONCLUDING REMARKS

Up to 1950, in a richly wooded country like Austria, roundwood was mainly used in the construction of protection structures for erosion control works. This roundwood was harvested and processed in the immediate vicinity of the torrent. In order to increase the durability of the timber, it was impregnated with wood preservatives. The timber proved to be a very good construction material, particularly on unstable slopes, since it is elastic and keeps up with the soil creeping without breaking and losing its efficiency.

The relatively short lifetime, the high expenditure for the work, the increasing labour costs (220 Austrian Schilling 1/per effective working hour) and the use of heavy earth-moving machinery after World War II, made it necessary to replace timber with concrete and stone rock.

High expenditures for erosion control are curbed in Austria today through far-sighted planning by preventing human settlements from being built in areas which are endangered by torrents. These zones which may be threatened by torrents and avalanches are shown on maps. The law requires that these danger zones must be either kept completely free of buildings or be settled only under specific protective prevention measures and conditions; in this latter case, the preventive protective measures must be carried out by the owner of the building and not by the public, but under public regulation and scrutiny.



Construction of dry stone training wall to protect river banks.  
In the background, check dams protect bridge (Photo: T. Pasca)

1/ 1 US\$ equals approximately 16.5 Austrian Schilling.

## TECHNIQUES IN WOOD HARVESTING WITH A VIEW TO INCREASING WOOD PRODUCTION AND SAVING ENERGY

by  
Ernst Pestal  
Universität für Bodenkultur 1/

### 1. INTRODUCTION

Increasing production is easy if sufficient quantities are available. Saving fuel is easy if it is accompanied by a reduction in timber production. Our aim, however, is to increase timber production while at the same time reducing energy consumption. Our efforts to reach this objective must be focused on the following areas.

### 2. PRODUCTION INCREASES

Which wood can be harvested over and above the present quantities without damaging the remaining stands? Small-diameter, wood felled for silvicultural reasons. (It must be remembered, though, that harvesting small-diameter wood requires a dense road network).

Another reservoir to be tapped for increased production are forests at high altitudes which have so far been considered inaccessible. These may and should be exploited with maximum care.

A third potential quantity increase may be expected from branches and roots. A moderate harvesting of branches is permissible if the brushwood is left at the felling site. However, in mountainous terrain roots and stumps must remain in the ground as they prevent run-off of precipitation water from causing large-scale erosion. Additional timber resources can be created by reforestation of barren land and abandoned farmland.

### 3. ENERGY SAVINGS

Views about how long earth's oil and coal reserves will last vary widely. So far, only one thing is sure: the less we waste, the longer they will last. An economical use of energy from any source is therefore of paramount importance even in countries which still believe that they do not need to conserve energy (at least for the time being).

Terrain permitting, partly-mechanized wood harvesting by power saw and wheeled skidder is still the cheapest method. Fuel consumption for transporting the felled timber to the processing plant, however, still averages  $3 \text{ l/m}^3$ , if the timber remains in bark. Cable transport reduces the fuel requirement by one third per  $\text{m}^3$ . If gravity can be used in cable logging, further fuel savings can be achieved. Sundberg estimates that, depending on diameters, another 1 to 1.5 l of fuel equivalent are required for the rotatory debarker in the processing plant.

As a rule, production increases and fuel savings can be achieved simultaneously when the manual work input is higher. A change-over from skidders to cable installations means higher wage costs. In countries where fuel costs are already exorbitant or considered unacceptable, a change-over to cable transport becomes inevitable.

In flat and hilly terrain wheeled tractors equipped with cable winches will certainly continue to be employed in the future; but to save fuel they will primarily be used as cable devices and road travel will be kept to a minimum. For moving their own weight, wheeled

tractors need twice the energy required for transporting a load. This is the main reason why wood harvesting by wheeled vehicles is highly fuel-intensive.

In countries with an abundant supply of labour, cable transport offers an advantage: for such economies it is an effective and productive means of creating jobs.

In its initial phase, however, it requires a high training input. Without properly trained operating personnel a cable installation breaks down more easily than wheeled vehicles.

This is a promising area of activity for you and your colleagues; and I am very pleased to address you here at Ossiach, which has become the centre of instruction for cable technology.

### 3.1 Timber transport by gravity and muscular strength

Muscular strength is assuming an increasing importance in silviculture and in the harvesting of small-diameter wood. In mountainous terrain, gravity is an additional energy source which is always available free of charge. By combining the two, wood can be cheaply transported down the mountain. The only auxiliary instrument required is the hookeroon (alpine peavie). Particularly for small-diameter wood, small timber quantities and short transport distances, manual gravity skidding is a valuable method. Forty percent of all Austrian timber is still logged in this way.

Animal skidding is gaining ground again, mainly in thinnings. Since horses are among man's competitors for food, oxen and buffaloes are more likely to be used, although ruminants are slower than ungulate animals.

Skidding by muscular strength shows that to a certain extent man is also an efficient "muscular machine". In the course of many thousands of years he developed from a hunter and scavenger into a farmer and worker, adjusting his body to his new mode of work.

It is important to humanize working conditions. Wood workers should not carry the timber but drag it. They should not be required to work under excessive time pressure. Reductions in the number of working hours make no sense if it means a proportional increase in working speed.

One hundred years ago our forest workers earned rather modest incomes. On their way home from work they used to sing their typical work songs. Today they earn more than most industrial workers but they can no longer be heard singing in the woods. This goes to show that their enjoyment of life has not increased to the same extent as their incomes, quite the contrary is true.

### 3.2 Fuel-saving cable systems

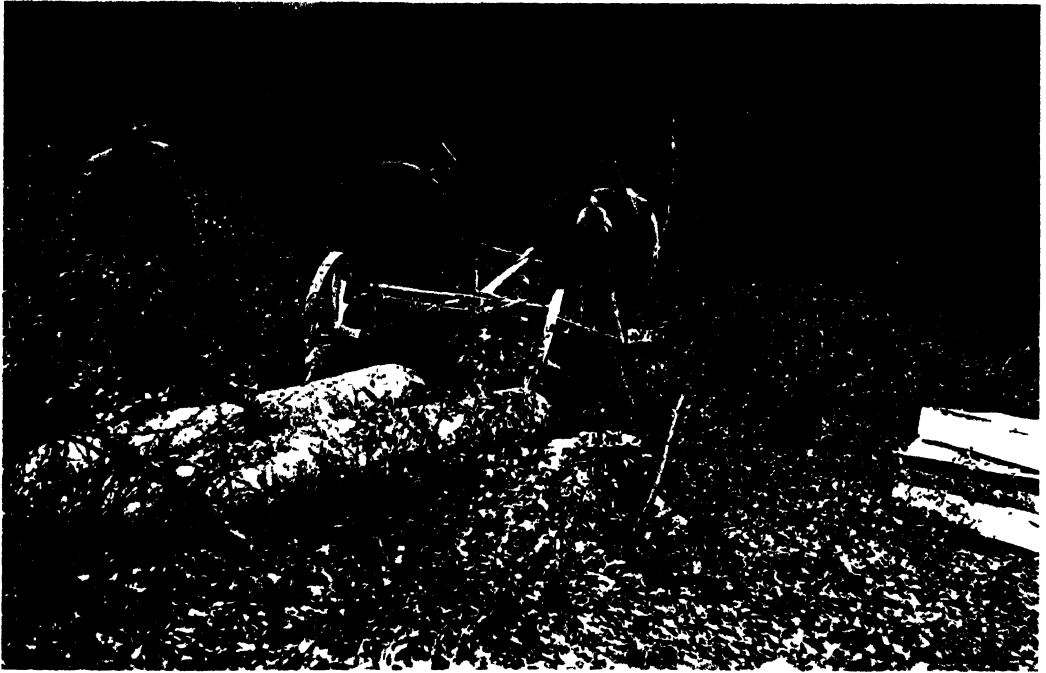
Austria's favourable geological conditions and ownership structure have paved the way for many different but integral types of cable installations. All systems which are suitable for mountainous forests, from small cable winches of as little as 20 kg to huge equipment weighing over 30 tons, are in use in this country.

#### 3.2.1 Power saws attached to winches

The smallest cable devices for uphill transport are power-saw winches. These are used where larger cable winches cannot be installed, for instance for clearing routes or for harvesting small quantities of timber up to the road.

Since power-saw and sledge winches weigh very little, they have to be tightly anchored to prevent them from rearing up or swerving to either side.





Traditional wood extraction by horses, using a two-wheeled wooden cart  
(Photo: E. Pestal)



Transport of bundles of twigs and branches by cable (Photo: Wyssen)

### 3.2.2 Cable winches mounted on wheeled tractors

The early self-propelled cable winches have been replaced by cable winches mounted on wheeled tractors. Experts recommend modern tractors to be equipped with additional front-wheel-drive and safety (roll-over protection) cabs. Farmers owning woodlands prefer to use their older tractors for timber harvesting, as a new one would be too precious for the demanding woody terrain. As a rule, a cable winch attached to the tractor's three-point hydraulic system may pull the timber over a distance of up to 50 m, in rare cases up to 80 m. Subsequently, the timber is slightly lifted by means of a hillside support or the fair lead of the skidding plate and pulled to the landing on the road.

In the past, timber had to be piled manually to form one load; nowadays this is done by use of choker chains.

### 3.2.3 Short-distance cable cranes

If timber is skidded over long distances, the operator's fatigue and risks of accident increase. It was for this reason that Stefan Gnezda, a foreman in the Slovenian Idria forest enterprise, invented a simple short-distance cable crane. Today simple and cheap cable cranes are in high demand all over the world, so Gnezda's invention is in great demand.

### 3.2.4 Cable cranes with collapsible tower

If wages are high, the time required for mounting the Gnezda(traditional)cable crane becomes a problem. To reduce it, several producers have mounted collapsible towers on tractors and powered the winches with the hydraulic system of the tractor. The cheapest and therefore most frequently used system is the Koller - K 300.

Cable cranes with collapsible towers are the easiest to use for uphill transport with one end of the log raised off the ground. Only a part of the load is raised by the mainline, so the mainline may be relatively thin, the anchor trees may be small in diameter, and the intermediary supports short and therefore cheap to rig. The device was originally designed for thinnings, however, it is also used for sawmill wood if the load does not exceed 1 m<sup>3</sup>.

There are also heavier types of cable cranes with collapsible towers. These are used if there is sufficient timber at the felling site to justify transport, mounting, and dismantling of the installation. Some of these heavier types will be shown in the subsequent film. It is up to you to decide whether they are useful for your purposes or not.

### 3.2.5 Long-distance cable cranes

Long-distance cable cranes using gravity can cover distances of up to 3 km and height differences of up to 1 000 m. They require careful planning and setting-up. Fuel consumption is low because the carriage is empty when it is pulled up. The main strain is on the brakes.

I want to emphasize the value of long-distance cable cranes in this respect: it has never happened that sheep or cattle use the cable corridors to destroy the terrain or that "conquerors" take advantage of them to burn down the remaining trees or drive a plough into woodland soil until rainwater erodes it. Long-distance cable cranes are a guarantee for the conservation of the woodlands, which is more important than anything else in many parts of the world.

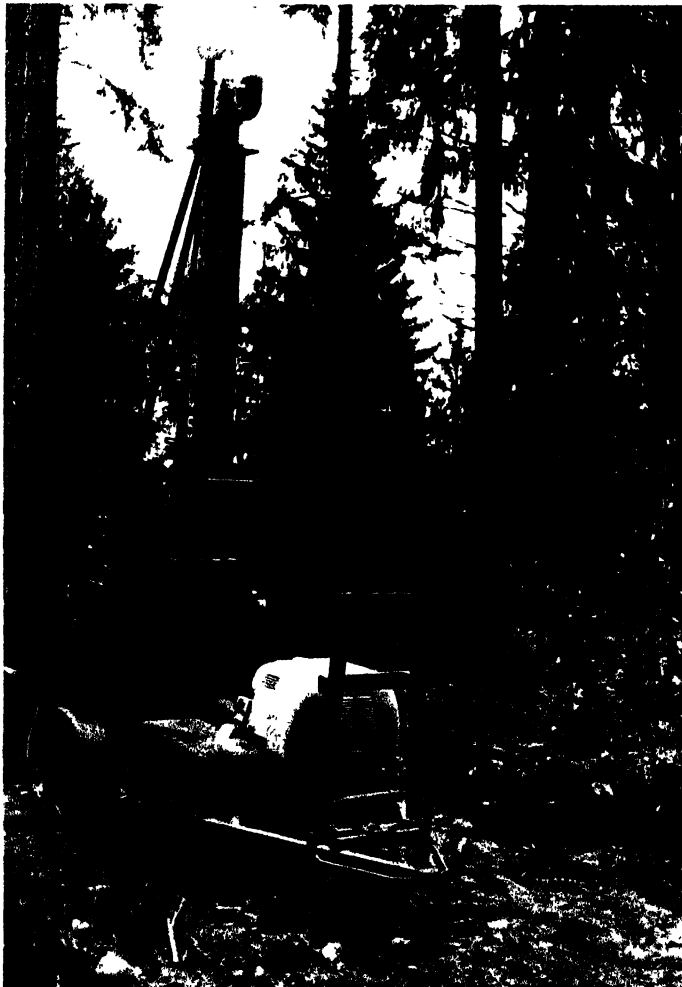
## 3.3 Highly-mechanised timber harvesting

The term "highly-mechanised" harvesting was chosen to differentiate this method from "fully-mechanised" harvesting, as it is used in Scandinavia but not feasible in mountainous terrain. For felling, the power saw is still used since felling machines are likely to tip over if used on too steep a slope.



Simple cable logging system (Gnezda) used for short-distance log transport  
(Photo: E. Pestal)

The topic of my paper excludes highly-mechanized systems since on an average they use 6 l of fuel per m<sup>3</sup> of timber, without bark. This is twice the amount of the partly-mechanized tractor system. It is true that wood processors for large dimensioned wood are efficient machines for delimbing and bucking but for the delimbing operation many forest owners change over from power saw to axe to save petrol, and at the same time to protect their workers against vasoneurosis. Working with the axe exercises the heart and lungs and is a good preventive measure against the harmful effects of power-saw work.



Mini-Urus trailer equipped with cable equipment, tower and engine to be used as short-distance cable crane in thinning operations or for small sized wood in final cuttings (Photo: E. Pestal)

# PLANNING OF WORK SYSTEMS FOR WOOD HARVESTING IN MOUNTAINOUS REGIONS

by

Winfried Egger  
Generaldirektion der Österreichischen Bundesforste 1/

## 1. INTRODUCTION

In planning a work system, the ideal work situation must first be identified with due regard to all elements which influence operations (forest enterprise, market, personnel, finance, etc.). Only on this basis will it be possible to determine what is feasible under the given circumstances.

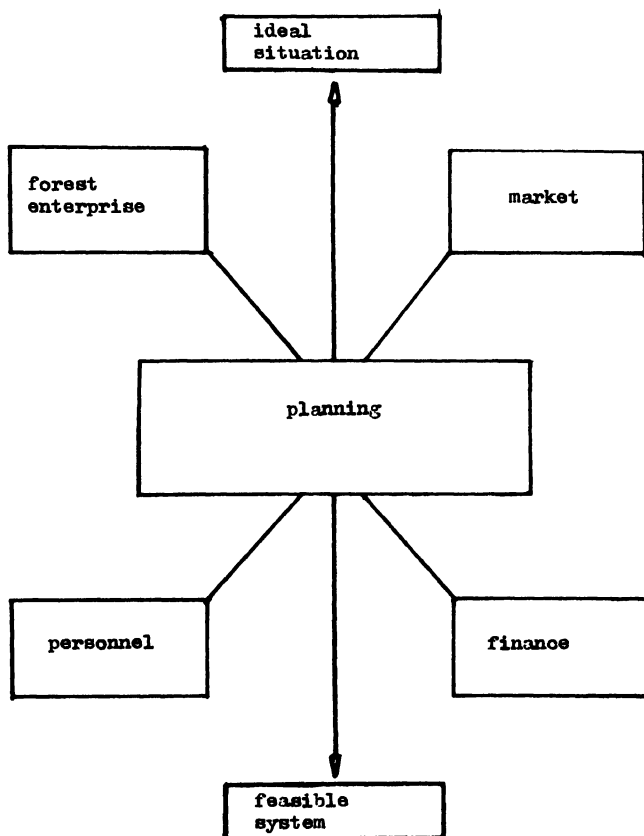


Fig. 1 Elements to be considered, influencing wood harvesting

Translated into wood harvesting, this means that all individual operations must be considered as forming part of a single work system.

As the elements of such a work system are closely correlated, they exert a decisive influence on the work to be done and on the performance to be expected. It is the objective of work planning to evaluate the individual elements of a work system and to determine accordingly the conditions under which the work should be performed.

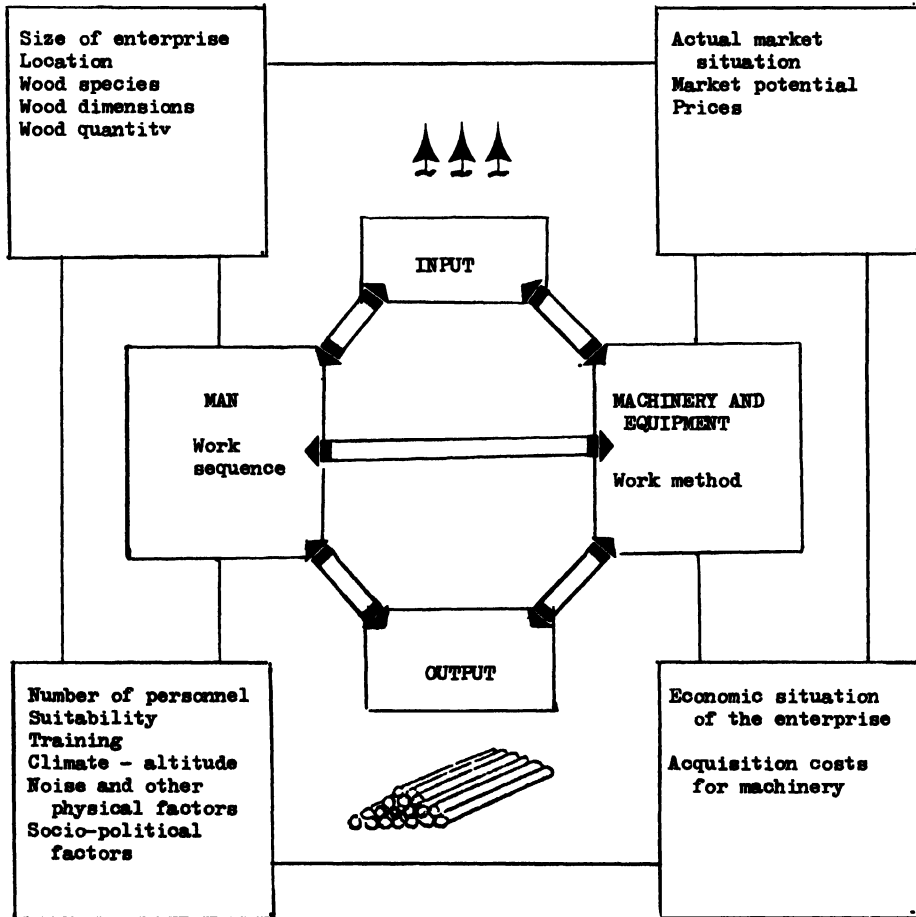


Fig. 2 Work system for wood harvesting

As can be seen from the above figure, the work system consists of an outer and an inner circle.

- a) The outer circle is usually beyond the control of the work system planner. It includes such factors as:
- i) the size of the enterprise  
The location and terrain where the work is to be carried out, the timber species (broadleaved or coniferous trees), the size of timber (diameter), the volume (number of cubic metres) to be harvested
  - ii) the market situation  
Sales prospects of the timber to be produced, selling prices, etc.
  - iii) the economic condition of the forest enterprise  
What is the financial position of the forest enterprise? Does the enterprise have sufficient capital?
  - iv) the cost of machinery  
What is the cost of machinery? Can the enterprise afford to buy a certain machine? What are the logging costs?
  - v) the personnel of the forest enterprise  
Are personnel available in sufficient numbers? Are they qualified? Are they properly trained or can the qualification level be raised through adequate training measures?
  - vi) the climate and the altitude  
Is the work performed in winter or in summer? At what altitude?
  - vii) the prevailing social conditions  
Influence of noise, physical conditions affecting man at work and so on.
- b) The inner circle must be conceived with due regard to the outer circle. The inner circle chosen by the planner determines both the input (in our specific case this is the forest), and the output of the work system (i.e. the assortment produced which is ready for sale). In short, the question must be raised: "By what means and in which way is the product made?". Here, man and the machinery and equipment he uses must be carefully studied so that the optimum low-cost harvesting system can be chosen. For this purpose, the work system planner must take very specific action:

Measures to be taken	Effects
Opening up the forest (road-net)	Higher efficiency
Work method (forest machines)	Increased output and safety
Personnel (number and qualifications)	
Basic training	
Further training	
Remuneration	Economic improvement

The first measure of work planning consists of opening up the forest through the construction of a forest road network in the best possible way. The general opening-up plan must take into account the type of machinery to be used, because this will influence the detailed opening-up plan.

An optimum road system based on the available mechanization options in wood harvesting offers a number of advantages, among which cheaper production, less strain on workers and a reduced risk of work accidents deserve particular mention.

Another essential task incumbent upon the work planner is the development of timber harvesting procedures, which must be tailored to the specific conditions prevailing in the enterprise and which must guarantee safe operations. On the basis of the three production factors, forest, man and machine, the harvesting method best suited to the biological, social and economic needs of the enterprise is then selected.

Here, of course, three goals (target performance, work safety, and preserving the healthy state of the forest) must be properly harmonized.

Every planner must seek to use mechanization as a means to facilitate work, to heighten safety and to increase work productivity. The supply of labour (labour market situation and social conditions) should, however, not be overlooked.

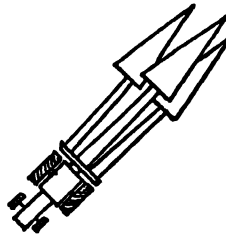
The work method must be chosen and the required forest machinery selected in accordance with these factors.

## 2. HARVESTING SYSTEMS CURRENTLY USED IN AUSTRIA IN MOUNTAINOUS REGIONS

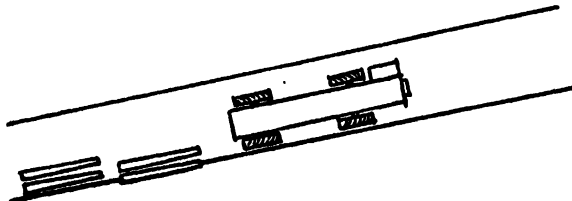
In forestry it has become common practice to name the three basic harvesting methods after the state in which the timber is logged.



1. Felling



2. Skidding



3. Either employment of mobile processor or transport to timberyard and final processing at the mill.

Fig. 3 Whole-tree method



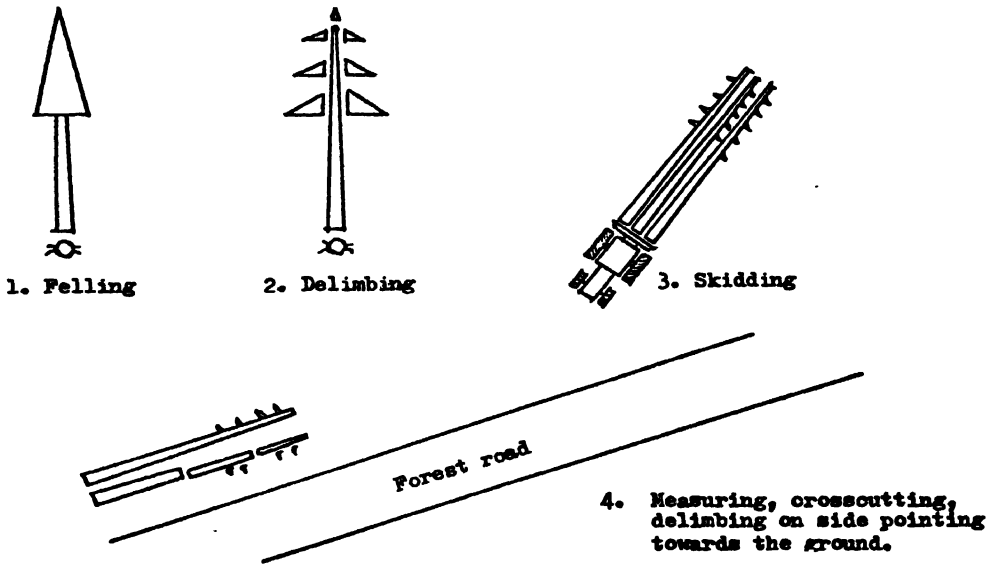


Fig. 4 Full-length method

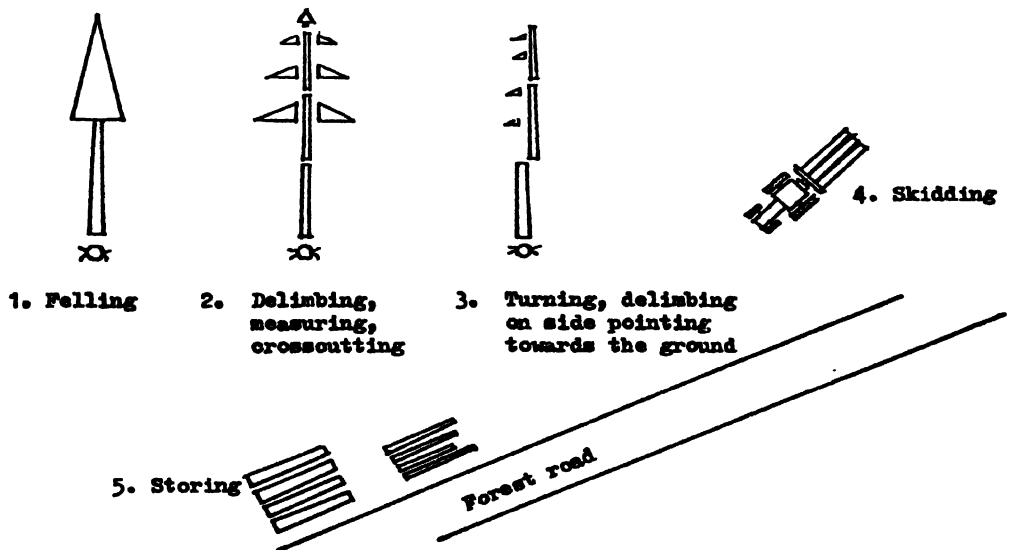


Fig. 5 Assortment method

There are, of course, variations for each method. Each of the methods described below may be the most suitable one under the given circumstances.

The widely held view that the most highly mechanized method is the best one, is simply not always correct. In order to arrive at a correct decision, it is imperative to study not only the costs but also the environmental influences of the work method (man and forest); thus the impact of the outer circle of the system must be given due consideration in order to be able to avoid adverse consequences.

## 2.1 The whole-tree method

Felling with the aid of a power saw. Transporting the trees to the conversion site or to the road by means of a skidder or cable.

Mechanized conversion using a field processor or a mobile processor, etc. (delimbing, bucking, debarking).

## 2.2 The full-length method

Felling, delimbing on the upper side of the log, using a power saw at the felling site; transporting the logs to the conversion site or to the road (skidder), conversion (bucking, final delimbing by means of a power saw).

## 2.3 The assortment method

Felling and conversion into assortments at the felling site, using a power saw; transporting the assortments to the road (skidder, articulated wheeled skidder, cable crane, manual skidding, etc.).

Investigations carried out by the Austrian Federal Forest Enterprise have shown that the assortment method (i.e. the conventional harvesting method) is the most expensive one in mountainous terrain; the full-length method is 34% cheaper than conventional harvesting, and the whole-tree method proved to be approximately 30% cheaper than the conventional system.

Harvesting costs expressed in % compared with the conventional harvesting method				
100%	82%	81%	70%	66%
conventional harvesting with our own personnel and our own skidders, manual debarking	conventional harvesting with our own personnel, skidders from farmers, manual debarking	partly mechanized harvesting with our own personnel, skidders from farmers, manual debarking	highly mechanized harvesting with our own personnel, mobile processor, mechanical debarking	partly mechanized harvesting with our own personnel, field processor, timber left in bark, adjusted for price reduction

Fig. 6 Comparison of harvesting costs with the Federal Forest Enterprise

In work planning, not only costs, but also the proportion of wages to costs (which vary with each harvesting method) must be taken into account.

95%	69%	36%
conventional harvesting	partly mechanized harvesting using a skidder	highly mechanized harvesting

Fig. 7 Proportion of wages to costs for the three different harvesting methods

Generally speaking, the assortment method is most appropriate when small volumes are to be cut per felling area (up to 150 cubic metres) or when skidding distances (up to about 100 m) are short. If landings and terrain are extremely difficult, the assortment method is also advisable. It is preferable in thinning (logs and double length logs) or in selective tree harvesting (single tree extraction) because major damage to the remaining stand is thus avoided.

Large quantities of timber, long skidding distances and clear cuttings, as well as minor preparatory cuts are factors which would justify the full-length method, provided that adequate conversion sites and suitable skidding machinery are available. As regards terrain, the full-length method using a skidder (articulated wheeled skidder with a winch) has proved satisfactory in areas with an average slope of 45-50 percent for downhill skidding and 25 percent for uphill skidding.

The whole-tree method requires a careful study of such factors as the volume of timber to be harvested, as well as transport and skidding options. Cost estimates and volume calculations are a valuable source of information for decision-making.

In view of the heavy loads involved and the high friction caused by the branches left on the tree, more powerful skidders are required in whole-tree harvesting than is the case with the full-length method.

In selecting the machines for the various harvesting methods, the planner must make sure that these will meet the requirements of the individual project (work, workers, performance and costs).

The machine must be adequate for



Fig. 8 Choice of machine

A machine can be suitable for the work only if it has been designed for the particular type of terrain and work process (cross-country mobility, favourable weight-performance ratio, etc.). Damage to the remaining stand, to the forest floor, to the assortment produced, and to the road and landings should be kept to an absolute minimum.

A machine can be adequate to the worker only if it meets ergonomic principles and requirements. Its design and safety features must be such as to guarantee easy, convenient, and safe operation. These factors are pre-requisites for the worker's sustained performance.

A machine can be efficient only if, in addition to the above-mentioned criteria, it permits safe and reliable operation as well as the worker's sustained performance under normal working conditions. Before purchasing a machine, its specifications should be studied in relation to the work required of it. Profitability is, of course, another criterion of paramount importance. A machine can be used profitably only if its purchase price is reasonable or low, if it can be employed at its rated capacity, and if its operating and repair costs are low. If it is used to 60 - 70 percent of its capacity, satisfactory results can be obtained. Its purchase price should always be looked at in relation to the unit of production (cubic metres).

A number of scientific institutes (Federal Forestry Research Institute, Schönbrunn, for example) have worked out checklists containing all the above-mentioned criteria. However, suitable and specially trained personnel are always needed to carry out economic and ergonomic studies and for selecting the right types of machines.

It is the planner's task to make sure that adequately trained personnel are available in sufficient numbers. These personnel must constantly receive more training. Only the most qualified forestry personnel, who receive continuous instruction and are under constant supervision, are capable of fulfilling their tasks economically, safely, and with due regard to forest conservation.

With an ever greater mechanization of wood harvesting, the training level of the personnel involved must also rise. Specific training should be offered for each harvesting method.

A machine will not do the work by itself.

It would be completely wrong to believe that planning consists merely in the acquisition of machinery and the intention to apply a certain work method. The more highly mechanized the harvesting method, the higher will be the planning and organizational input.

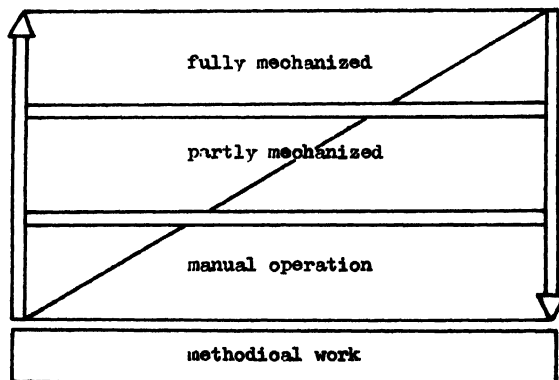


Fig. 9 Work planning and organization

Another decisive factor in choosing a particular work method is the wage system used. In planning work adequate earnings must be assured under normal working conditions for all well-trained workers who are familiar with their job and who have sufficient experience. Motivating workers is the proper and right thing to do! But excessive stimulation resulting from an extreme incentive wage scheme can be very dangerous, as this could present a threat to the life and health of the worker and lead to excessive wear on the machine, as well as to damage to the remaining stand through over zealousness.

A fair wage system would have to combine a time wage element and a performance-related wage element (piece-rate or premium wages).

The planner must choose the right wage system for the type of job to be performed. Here it has been found that a piece-rate system is very well suited for the assortment method, whereas for the combined harvesting methods (whole-tree and full-length) where heavier machines are used, the premium system (basic wage plus performance-related premium) is normally applied.

Performance, work safety and the health of the forest are not determined by one single worker! All people involved in the work process contribute to the results. Assuring that this triple goal can be reached is the particular responsibility of the planner. He must be aware of his function and act accordingly.



Processor picking up tree length logs for debranching, debarking, cross-cutting and making assortments (Photo: O. Sedlak)



Timber chute used before mountain forests were made accessible  
by forest roads (Photo: O. Sedlak)

## APPLICATION OF INTERMEDIATE TECHNOLOGY IN WOOD HARVESTING IN DEVELOPING COUNTRIES

by

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### 1. INTRODUCTION

In the last few years in many industrialized and developing countries throughout the world, a significant change in the role of forestry vis-à-vis the public at the country or country level, has taken place as far as utilization patterns, the formulation of forest policies and future action programmes are concerned. In most countries in the past, forests were primarily managed to satisfy the needs of forest industries and only in recent years there has been an increasing awareness of the importance of the role of forestry in the environment. Now it seems that, at least in many developing countries, the production of wood for energy use (fuelwood, charcoal and/or wood gas) has become more and more important. Quite a few forestry departments have therefore launched large-scale afforestation programmes to establish new forestry plantations to satisfy local and/or regional energy needs; by involving the masses of the rural population FAO has established a programme which is called Forestry for Local Community Development (FLCD), to support this movement in many developing countries.

Developed countries are also thinking of the establishment of so-called energy forests to study costs of harvesting wood for energy use (for instance in Austria and Sweden).

This change was determined by two main factors; the ever rising oil prices and the foreseeable scarcity of natural oil and the increased needs of an expanding world population. Now you will wonder what all this has to do with forestry in general and logging in particular. Due to the high inflation rates in many countries all over the world, cuts in costs and re-orientation in the production are required in many sectors of trade, industries and services. As far as logging is concerned, many developing countries are seeking advice on how to cut down on investment costs, logging (extraction equipment), reducing fuel costs. To put it in general terms, to cut down wood production costs. On the other hand, in many developing countries there is a need for increased employment, especially in the rural areas. Very often the above-mentioned objectives can be achieved by scaling down the logging machinery to be used, by improvements of the organizational structure, by specialized training and proper maintenance of machinery and equipment.

### 2. LEVELS OF WOOD HARVESTING OPERATIONS

Principally three major different levels of harvesting operations can be distinguished:

- Labour-intensive logging operation;
- Intermediate technology logging operation;
- Fully mechanized logging operation.

#### 2.1 Labour-intensive logging operations

In this type of operation, as the name indicates, manual labour is the main input. With the help of good quality and appropriately maintained forestry handtools, developed for the different types of forestry work, quite remarkable results can be achieved in

wood harvesting operations. As far as the moving of logs is concerned, very specialized traditional methods have been developed in various parts of the world; some of them are still being practised, especially where manual labour is still cheaper than the use of machinery. Just to give a few examples, in mangrove and fresh water swamps, logs are moved by hand in man-made water channels and ditches; on level soft soils skid trails are often prepared in order to roll logs to landings; in steep terrain with the help of hookerons (peavies) logs are moved downhill, or by skid pans, sledges and chutes. In some instances, animal skidding and transport of logs have partly substituted for the purely manual movement of logs.

## 2.2 Intermediate technology logging operations

In this operation only limited manual labour is used and machinery is introduced to facilitate the work and improve the production output. For instance for felling, the hand-saw is substituted by the chainsaw, whereas for debranching the axe is still often used. For off-the-road and on-the-road transport, farm tractors with forestry attachments (winches, trolleys, cable crane attachments and trailers) will do a sufficiently good job in many cases. The limiting factors for the introduction of these types of intermediate machinery is very often the size of trees and the accessibility of forests (terrain, soil and road-net density).

## 2.3 Fully mechanized logging operations

In most industrialized countries a high level of mechanization is generally applied, this being dictated by the high cost of labour and the need to guarantee a steady supply of a large quantity of logs to established forest industries and consumer markets. But in some developing countries we can also find highly mechanized logging operations, especially in tropical forests where the large size of trees and thus logs are too heavy to be handled by small machinery and hand labour is not available in sufficient numbers because of the remoteness of the forest areas.

In developed countries, in easy terrain, mechanization of large-scale harvesting operations has advanced to such an extent that a single machine now carries out the various jobs of felling (shearing, cutting), debranching, bucking and debarking. In difficult and steep terrain, however, a couple of machines are still required for the production of logs; often the following sequence of machines are used: chainsaws for felling, cable cranes for extraction of trees and transport to the roadside, skidders to transport trees to the landing where a processor finally is employed to delimb, buck and debark the trees.

In tropical forests nowadays felling is primarily carried out by heavy-duty chainsaws, and extraction of logs by a combination of crawler tractors (pre-bunching of logs to main skidding paths) and heavy-duty articulated wheeled skidders. In recent years a new machine, a tracked skidder, has been developed to work along with crawler tractors in wood extraction.

## 3. APPLICATION OF INTERMEDIATE TECHNOLOGY

The concept of using intermediate technology in forestry operations and especially in logging (extraction and transport) derives mainly from the changes in the economic situation of many countries of the world, especially with regard to energy consumption, its use and costs. It also originates from an awareness of the needs to preserve forest resources through improved environmentally-oriented efficient operations and to increase forest resources through new plantations. A careful look must be taken in order to choose the correct size/power (kw) of machines because of the high fuel costs in non- or limited oil-producing countries on the one side, and because of labour costs in industrialized countries, on the other. For this choice one has to take into consideration manpower availability and needs



in order to come up with more economic solutions in wood harvesting. This is particularly important for the newly established forests to be used for energy production.

#### 4. REVIEW OF INTERMEDIATE LOGGING TECHNOLOGY MACHINERY

When we are speaking about intermediate technology, we are thinking basically of using the agricultural tractor (with a power supply of 50 to 80 hp) with special forestry attachments which have been developed in the past, but specifically in the most recent years, for the various jobs needed in logging and transport operations. This type of equipment is produced mostly in developed countries and is already generally widely used. However, it is a fact that it is still little known in the developing countries.

One aim of the paper, therefore, is to give you an overall view about existing logging equipment to be used mostly in combination with agricultural tractors which may be of interest to some of the logging requirements in your country; and secondly, to report on a comparative time study carried out in Mexico in which simple and intermediate logging technology, and tools, equipment and machinery were used.

As far as the agricultural tractor for forestry work is concerned, it should have the following:

- Four-wheel drive tractor with a roll-over protective structure (either roll-over frame or safety cab);
- Three-point linkage (except for those forestry attachments which are directly mounted on the tractor);
- Power take-off;
- Bottom safety shield (a pan to protect the engine);
- Power source of from 50 to 80 DIN <sup>1/</sup> hp.

With reference to the attachments for forestry work, we would like to give you a few examples of presently utilized tractor attachments which may be essentially grouped as follows:

- Tractor-mounted grapples for skidding logs and shortwood;
- Tractor-mounted winches with or without logging plate;
- Tractor-attached winches with or without logging plate;
- Tractor-attached logging trolley (bogie);
- Tractor-attached mobile tower cable cranes;
- Trailers for transport of logs and shortwood.

In addition to the above-mentioned tractor attachments, independent ground skidding winches (with or without radio or remote control) have been developed and refined in recent years. Another remarkable innovation is the polyethylene chute which is used to slide pulpwood and firewood downhill.

##### 4.1 Tractor-mounted grapples for skidding logs and shortwood

The tractor-mounted grapple attachment is very useful for a one-man operation in easy

terrain. The use of this grapple generally requires that the tractor be able to move towards the felled trees or logs to pick them up in the terrain; however, in addition, some grapples are equipped with a winch in order to also use them in more difficult terrain. Normally, the grapple can handle everything from very small to large dimensioned trees and logs (say poles, trees or logs with diameters ranging from 8 cm up to 110 cm).

A list of a few firms which manufacture grapples and tractor attachments is given below:

- for log skidding (Farmi, Kuzmann, Ruttnig, Loft);
- for shortwood skidding (Norgaard, Kärntner Maschinenfabrik).

For easy reference, a picture of a tractor-attached grapple with a single drum winch added, is shown below:



Grapple with a single drum cable winch (Photo:FFP 1/)

The winch has a power line pull of 4 000 kp, with a cable capacity of 60 m when using a 12 mm  $\phi$  cable. The medium cable speed is about 0.5 m/sec. The whole attachment, without the cable, weighs about 470 kg.

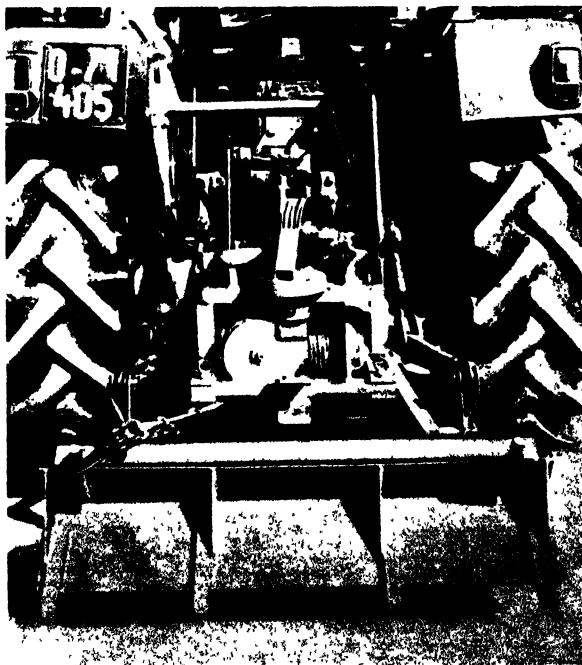
Purchase prices for different types of grapples range from approximately US\$ 2 000 to US\$ 5 000 <sup>1/</sup>, depending whether required for a light or heavy duty job.

#### 4.2 Tractor-mounted winches with or without a logging plate

These are winches which are directly mounted onto the rear of a tractor at the factory.

There are various companies which manufacture tractor-mounted winches, such as Adler, Glogger, J.H.B. Hydatongs, Huber and Gland, Lindner, Kuxmann, Nagel, Oesa, Ritter, Schlang and Reichart, Vögerl and Werner. They are either single or double drum winches with a maximum line pull capacity ranging from 2 400 to some 8 000 kp.

Most of the winch drums have a cable holding capacity of 50 to 80 m, but some have a capacity of 120 m; generally 12 to 14 mm  $\phi$  cable are used. Purchase prices range from some US\$ 4 000 to 8 000. As an example, the picture below shows a single drum winch (Vögerl) produced by Rittmann Maschinenebau with a logging plate.



Tractor-mounted single drum winch with logging plate (Photo:FFP)

The winch has a maximum line pull of 3 500 kp with a cable capacity of 110 m when using a 12  $\phi$  cable. As shown on the picture, a logging plate is recommended for operational and safety reasons.

<sup>1/</sup> All purchase prices quoted are only approximate quotations, generally from 1979 and 1980, given for information purposes only. They should be understood as ex-factory prices without customs and transport costs.

Note: 1 US\$ = 15 A.S. (February 1981).

#### 4.3 Tractor-attached winches with or without logging plate

These winches are attached to the tractor's three-point linkage, having single or double drums and are often equipped with a logging plate. Some of the winches have drums which are located parallel to the tractors' axles; others have them perpendicular. However, the latter type of winch needs a special fair lead. Instead of a logging or skidding plate, one manufacturing company produces a simple frame with bunks to stabilise the tractor while winching in the logs.

Some of the well-known brand names of tractor-attached manufactured winches are as follows: Farmi, Huber, Igland, Krasser, Norse, Ritter, Schlang and Reichart, Schwedenforst and Vögerl.

Winches generally have a maximum line pull which ranges from 1 500 kp to 5 000 kp. Maximum extraction distances for winching are 50 to 180 m depending on the size of winch and cable used. Cables of 8, 9, 10, 11 and 12 mm  $\phi$  are used for winching purposes; the most frequently used, however, is the 12 mm  $\phi$  cable.

Equipment purchase prices, depending on make and/or power required, range from approximately US\$ 1 200 to US\$ 7 000.

A picture of a very simple winch, the Farmi winch with a grapple, is shown below:



Wheeled tractor with Farmi winch and grapple  
(Photo: NORMET)

This winch has a line pull capacity of 3 000 kp, with a cable drum capacity of either 50 m when using a 8 mm  $\phi$  cable, or 75 m with a 10 mm  $\phi$  cable. Purchase price is about US\$ 1 700.

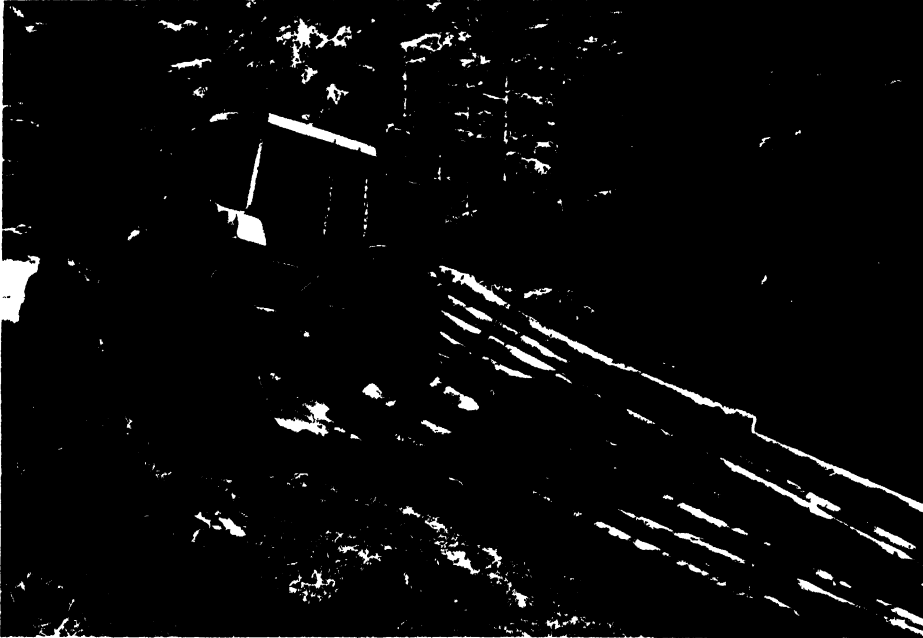
#### 4.4 Tractor-attached logging trolley (bogie)

This tractor attachment, for instance, is produced by Steyr and by Sohlang and Reichart. It is essentially a small trailer with 2 wheels, a single drum winch and a skidding plate. The function of the logging trolley is a double one, namely to winch and to transport. Winching distances can be either for a maximum of 75 m (12 mm  $\phi$  cable) or 110 m (10 mm  $\phi$  cable), according to the size of cable used.

The maximum line pull is about 4 000 kp. The interesting combination of this machine is that the log can be winched in on difficult ground and terrain to a skid or forest road from where the logs are then skidded (transported) to the road or landing. While the skid plate for the first operation serves as a safety protection structure, it acts as a transport aid by putting one end of the logs on the plate for the skidding phase (see photographs). The purchase price for the Steyr logging trolley is about US\$ 5 500.



Farm tractor with bogie used for uphill ground skidding (Photo:Steyr)



Farm tractor with bogie transporting the load (Photo: O. Sedlak)

#### 4.5 Tractor-attached mobile tower cable cranes

There are quite a few cable systems on the market, which are built to be used as attachments for agricultural tractors for cable crane operations, such as James-Jones, Koller, Urus mini and one which is just now under investigation: the Igland/Kubota system. The advantage of these systems versus the traditional cable systems is that because of the mobile tower cable equipment, rigging times are considerably reduced.

Thus logging can be carried out more economically in steep, difficult, marshy and swampy terrain than by using the older methods. As their spans are generally from 300 to 500 m in length, they are an ideal supplement to a basic road network system designed to make forests entirely accessible for harvesting purposes. Essentially one can distinguish two different types of cable systems: the high lead and the skyline operations. The different cable systems will be explained to you in more detail during the course; therefore, I will not elaborate on them here.

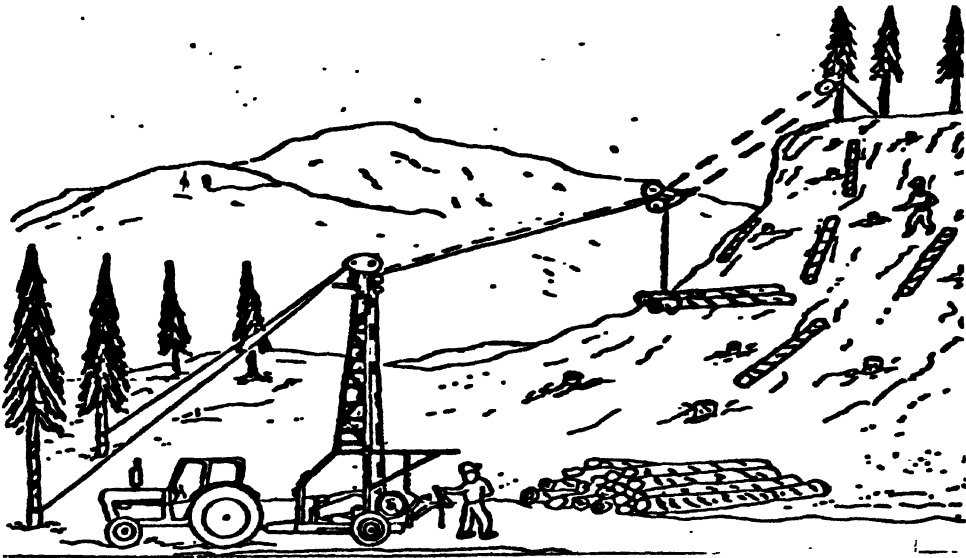
The above-mentioned machines are essentially used in plantation forests, for small-sized wood in clear fellings or thinnings; they are able to transport a maximum payload of 1.5 tons of logs.

A Koller cable system, for instance, costs about US\$ 30 000 whereas the James-Jones system will cost about US\$ 50 000. In addition, a power source (agricultural tractor) will still have to be purchased to operate both systems.

The following two pictures show two different cable systems in operation.



Koller 300 cable system extracting logs uphill to the roadside (Photo: FPP)



James Jones trailer Alp cable system extracting logs downhill to the road  
(Picture provided by James Jones)

#### 4.6 Trailers for transport of logs and shortwood

They are essentially designed for farmers and small contractors using tractors and trailers for transporting logs or shortwood over short distances. Special trailers like the Radolf-Zeller Rückewagen have been developed to transport shortwood, since it has a built-in hydraulic tilting device which makes unloading of shortwood very easy.

This trailer is single-axle with a load capacity of 2 steres if the shortwood is bundled; otherwise it has a load capacity of 3 to 4 steres, if the wood is loaded loose. The length of 1 or 2 metre is also a factor. The purchase price of the trailer is about US\$ 5 500.



Tilting a load of shortwood which had been transported by  
a(Radolf-Zeller Rückewagen) trailer

The same manufacturer also produces a single-axle trailer for transporting poles with a maximum loading capacity of 3 tons.

#### 4.7 Ground skidding winches

These are independent winches which are built to be used for extracting logs by ground skidding (winching), especially for small-scale operations, i.e. single logs from difficult spots and areas (gulleys, creeks, ravines, and broken terrain). They were also designed for small-sized timber to be extracted from plantation forests. Depending on the machine make, their line pull capacity runs from 600 kp to 2 200 kp. They are able to cover extraction distances which range from 80 to 165 m. Cable diameters of 5 mm, 6 mm, 6,5 mm, 7 mm, 8 mm and 9 mm are generally recommended to be used with these single drum winches. Some of the winches are equipped with a power chain saw engine, others with their own brand. The available hp for the different winches ranges from 4.5 to 16 DIN hp.

The weight of these winches varies from 42 kg to 560 kg. The 42 kg winch can easily be carried by hand, whereas the others will have to be transported by other means to the working area.

The winch is generally tied to a tree; the logger then has to pull the cable to the log, choke it and then, by means of radio control, the log is winched in (with the exception of the Akja winch). The Akja winch is built on a sledge and then one end of the cable is fixed to a tree and the Akja winch moves to the log to be extracted; the log is put on the sledge and winched in to the landing on the sledge.



One manufacturer produces a ground skidding winch which has its engine on a small single axle trailer; winch and engine are linked by hydraulic hoses. The trailer can be moved by hand to the place where log extraction is to take place.

Purchase prices for the above-mentioned winches range from US\$ 2 500 to 12 000, depending on the type and make.



Akja sledge winch  
(Photo Kärntner Maschinenfabriken Egger Ges.m.b.H.)

As mentioned before this winch is generally used for prebunching of logs; however, it is also very useful to transport cables and cable crane support material to the installation sites in the forest area. Another application is for placing the polyethylene chutes in thinnings. The sledge winch is equipped with a 4.8 Kw chainsaw engine, with a line pull of 800 kp, a 110 m cable (6.5 mm  $\phi$ ) having a total weight (including cable) of 70 kg. The winch costs about US\$ 2 500.



Multi KWF lightweight ground skidding winch (Photo KWF 1/)

This winch again is equipped with a chainsaw engine (Jonsereds) of 4.2 Kw, with a line pull of 1 000 kp and has drum capacity of 80 m when using 6 mm cable, or 150 m with a 5 mm cable.



Radiotir Alpin 1 200 (Photo KWF)

This winch is used with radio control and can be operated by a single man. It is equipped with 6 Kw engine, having a line pull of 1 200 kp, and it has a cable drum capacity of 165 m when using 7 mm  $\phi$  cable or 125 m when using 8 mm  $\phi$  cable. Its purchase price is approximately US\$ 9 000.

## 5. CASE STUDY ON INTERMEDIATE LOGGING TECHNIQUES IN MEXICO

The objectives of the studies were to identify intermediate logging techniques to improve efficiency in wood harvesting for farm forest owners, especially to reduce fatigue of manual labour by introducing appropriate low capital investment machinery and thus make the whole logging operations more economic for the worker, the contractor and the entrepreneur.

Altogether a series of 8 different studies with various degrees of mechanization were carried out, taking into consideration silvicultural aspects and requirements as well as terrain features. They took place in the coniferous forests near Perote, Veracruz, at an altitude of 2 400 to 3 000 m above sea level. The predominant species were pines, mixed with Abies sp. and cypress.

The areas were located in from flat to steep terrain (slopes with average gradients of 3 to 55%). The average DBH  $\frac{1}{2}$  of the trees removed during the tests ranged from 18 cm to 28 cm. Both clearfelling and selective cuts were performed in the logging trials. Investigations were carried out by means of time studies for which the multimoment method was selected and the results obtained were evaluated by means of a computer programme developed by the study team.

Through time studies, production and costs of the various methods, using alternative tools, equipment and machines, were evaluated and a comparative cost calculation for the different extraction methods was developed. The eight different logging methods studied were as follows:

- Study No. 0: The existing conventionally practised logging operation was studied, this being felling and cross-cutting carried out by handsaw and axe and skidding by a pair of oxen.
- Study No. 1: The same type of operation as described above was carried out; however, more efficient hand tools were given to the workers and, in addition, the latter were trained for a brief period.
- Study No. 2: Felling by handsaw, tree length skidding by wheeled tractor equipped with a double drum winch (Igland 5000).
- Study No. 3: Felling and crosscutting by chainsaw, extraction done in two different ways:
  - Variation 1: wheeled tractor equipped with double drum winch;
  - Variation 2: wheeled tractor equipped with a shortwood trailer.
- Study No. 4: Felling by chainsaw, extraction tree length logs by wheeled tractor equipped with a bogie.
- Study No. 5: Study on shortwood in thinnings, felling by handsaw, manual extraction.
- Study No. 6: Study on shortwood; felling by chainsaw, extraction by use of polyethylene chute (Leykam log line).

Study No. 7: Study in steep terrain; felling by chainsaw, extraction by use of cable crane.

Based on the experience of the tests carried out in Mexico the following conclusions can be drawn.

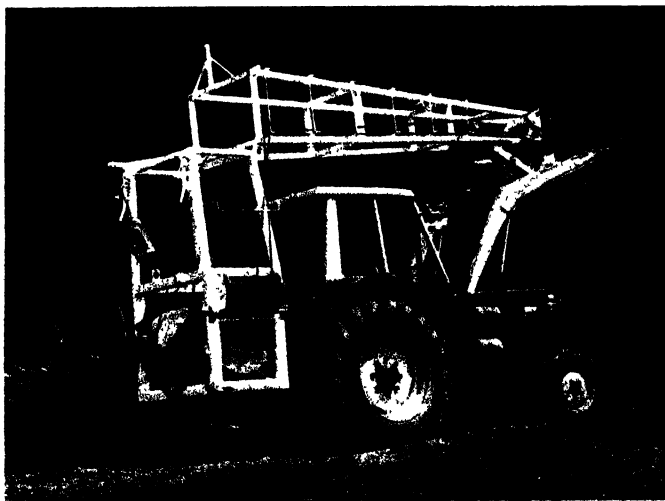
The traditional logging system can certainly be improved especially by providing work-oriented training to forest workers and small farm forest owners and/or logging contractors, as well as by introducing improved and properly maintained tools.

As far as extraction and transport methods are concerned, the manual method is the most expensive one. The traditional animal skidding, especially for shorter distances, is still compatible with the extraction performed by a wheeled tractor equipped with a winch. This is particularly evident when operators are not sufficiently trained.

The extraction method by farm tractor equipped with bogie turned out to be the cheapest one of all intermediate technology methods tested.

Moreover, the studies gave a clear picture that, in countries with low or rather low labour costs, a high level of mechanization is by no means justified economically. The level of mechanization, type of machinery and required Kw engine power, therefore, must be matched with the country's socio-economic background, always taking into consideration the characteristics of the forest as well as their environment (size of operation, tree stands and sizes felling coup, terrain, soil, infrastructure, manpower availability).

The basic data of the results obtained are presented in the form of two tables which are shown below. Table 1 gives essentially the productivity in m<sup>3</sup> per manhour and costs per m<sup>3</sup> in US\$ for the various operations. Table 2 shows comparative extraction costs calculated per m<sup>3</sup>, in US\$, for a skidding distance of 50 m.



Agricultural tractor equipped with K300 cable equipment ready to be shifted to next cable crane setting (Photo: E. Pestal)

Table 1 - Time study results in the pine forests of Parota/Vermorus

Study	Average slope	Average DBH	Pelling cut intensity	Type of operation	Equipment used	Production in m <sup>3</sup> per manhour	Costs in US\$/m <sup>3</sup>	Average extraction distance
<b>Study No. 0</b>								
Conventional method (assortment method)	3%	27 cm with bark	91% of total volume per unit area	Pelling & crosscutting extraction	handsaw and axe	0.77	0.76	50 m
					pair of oxen	1.19	1.23	
						Total	1.99	
<b>Study No. 1</b>								
Conventional method, but new tools and training of workers	3%	27 cm	80%	Pelling & crosscutting extraction	handsaw and axe	0.97	0.64	50 m
					pair of oxen	1.33	1.11	
						Total	1.75	
<b>Study No. 2</b>								
Free-length method	5%	28 cm	77%	Pelling extraction	handsaw and axe	1.99	0.31	80 m
					wheeled tractor with winch	2.63	2.85	
					crosscutting handsaw and axe	0.65	9.94	
						Total	4.10	
<b>Study No. 3</b>								
Mechanized assortment method	4%	28 cm	86%	Pelling & crosscutting extraction; Variation 1	chainsaw and axe	0.87	2.01	
					wheeled tractor with winch	1.71	2.37	Var. 1: 100 m
					Variation 2	0.54	4.12	Var. 2: 350 m
					wheeled tractor with trailer	Total 1	4.38	
						Total 2	6.13	
<b>Study No. 4</b>								
Tree-length method	3%	26 cm	84%	Pelling extraction	chainsaw and axe	1.76	1.65	
					wheeled tractor with bogie	2.50	3.02	
					crosscutting chainsaw and axe	2.74	1.95	150 m
						Total	5.72	
<b>Study No. 5</b>								
Shortwood method in thinnings	1%	18 cm	10%	Pelling & crosscutting extraction	bowsaw and axe	0.28	2.28	
					hookroons	0.50	1.17	30 m
						Total	3.45	
<b>Study No. 6</b>								
Shortwood method in thinnings	20%	19 cm	1%	Pelling & crosscutting extraction	chainsaw and axe	0.41	3.78	
					polyethylene	1.06	1.85	60 m
						Total	5.63	
<b>Study No. 7</b>								
Assortment method in steep terrain	5%	26 cm	40%	Pelling & crosscutting extraction	chainsaw and axe	1.18	1.49	
					wheeled tractor with cable			
					K300	0.68	4.22	80 m
						Total	5.71	

Table 2

Comparative costs of wood extraction for a 50 m distance

<u>Study</u>	<u>Method</u>	<u>Extraction cost per m<sup>3</sup>, in US\$</u>
No. 0	oxen skidding	1.23
No. 1	oxen skidding	1.11
No. 2	wheeled tractor with winch (untrained personnel)	1.78
No. 3	wheeled tractor with winch (trained personnel)	1.19
No. 4	wheeled tractor with bogle <u>in thinnings</u>	1.01
No. 5	manual extraction <u>in thinnings</u>	1.95
No. 6	extraction by chutes	1.54



Cone-type mechanical wood splitter attached to wheeled tractor (Photo: R. Heinrich)



Power saw winch used for prebunching individual logs from inaccessible areas  
(Photo: E. Pestal)

WORK SYSTEMS AND COSTS IN WOOD HARVESTING  
AND THEIR INFLUENCE ON THE FOREST WORKER AND THE FOREST

by  
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## 1. INTRODUCTION

Wood harvesting in Austria is carried out in a variety of ways. Varied conditions in the different parts of the country have led to the development of a wide range of harvesting methods.

According to the kind of machinery and devices employed and the state of the wood to be logged (assortment, full-length, and whole-tree method), we distinguish between three basic harvesting systems:

### 1.1 The least mechanized assortment method

Felling, delimbing and bucking are carried out both manually and by means of a power-saw. The assortments are normally logged manually or with the aid of simple machinery.

### 1.2 The partly mechanized full-length method

Felling and delimbing are carried out both manually and/or with a power-saw. Logs are delimbed on one side and topped, and skidded by means of special forest tractors. After skidding, the power-saw is again used for final delimbing and bucking of the logs, which are carried out on the forest road or at the landings.

### 1.3 The highly mechanized whole-tree method

A power-saw is used for felling. The whole trees with their branches on are skidded by special forest tractors. Subsequently, the trees are delimbed and bucked by processors. These operations are carried out right on the forest road, sometimes also at the landing, or after transport by means of trucks, in timber yards (this is rarely done with timber from thinnings).

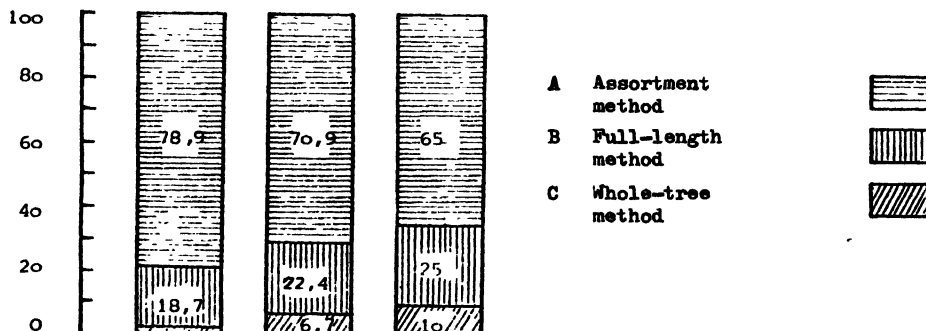


Fig. 1 shows the development of the three main wood-harvesting methods used and forecasted in Austria for the period 1975-1985.

Disregarding factors which cannot be influenced, such as the development of wages, purchase prices for machinery, fuel costs, etc., it may be said that, in general, increasing mechanization results in lower harvesting costs, at least in final cuts, provided that the work is planned and organized in the best possible manner and carried out expertly.

# % Costs

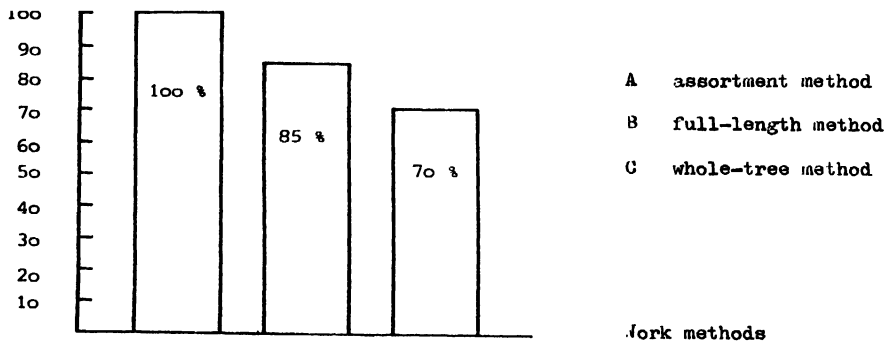
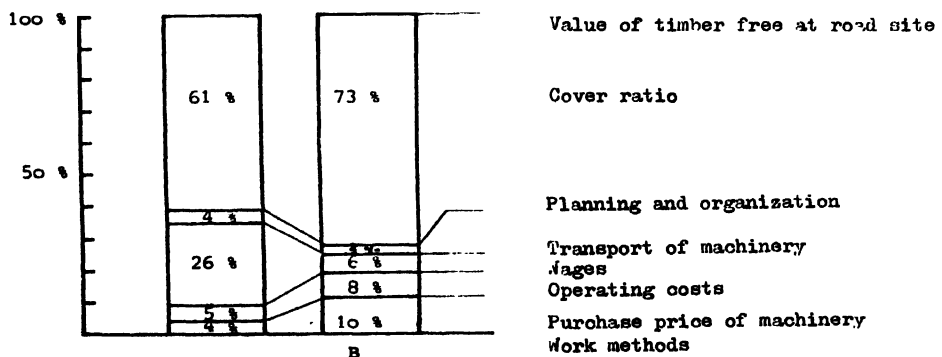


Fig. 2 Extraction costs in % of three different work methods.

The above percentages represent average values, which are derived from a cost comparison between the assortment method (= 100%), the full-length and the whole-tree method.

Costs vary with the area to be logged. In addition to mechanization, a number of other factors, such as wood diameters, the felling method employed, terrain conditions, as well as planning and organization measures have a considerable effect on costs. Cable logging is usually more expensive than skidding.



- A) Assortment method involving the use of a power-saw and an assortment skidder.
- B) Whole-tree method using a processor.

Fig. 3 shows, in a simplified form, a possible shift in costs which may occur when changing the work method in final cuts, in terrain which is accessible by skidders (source: Skogsarbeten, Stockholm).



The above percentages refer to the timber values achieved. (Timber value = 100%). This 100 percent is broken down according to purchase price of machinery, operating expenses, wages, planning and organization, as well as road travel of machinery. The remaining amount represents the cover ratio which is available for other purposes and which may include a potential profit.

This example clearly demonstrates the effect of mechanization on costs due to wages. Wage costs may also be equated with the time input required for manual work, which is not only valuable for lowering costs, but in some instances also for job creation, which may be a requirement of a given social policy.

Since in the present case the assortment method is very sophisticated and highly mechanized (using a forest skidder of special design), the cover ratio is only moderately affected by the high level of mechanization. Major increases in purchasing costs, operating expenses and a lower degree of utilization of available machinery, as well as reduced output due to an inefficient organization of work, etc., could result in a shrinkage of profits which could otherwise have been attained with mechanization, or even in deficits.

It is the primary task of work planners to identify such a negative trend and to avoid such problems by gearing mechanization to actual needs.

The degree of mechanization required in wood harvesting will vary in each case. In addition to the level of wages, the social conditions of a country, safety regulations or requirements and the weight of timber usually play a significant role in the analysis of costs on which decisions are based; therefore, all these factors must be given due consideration.

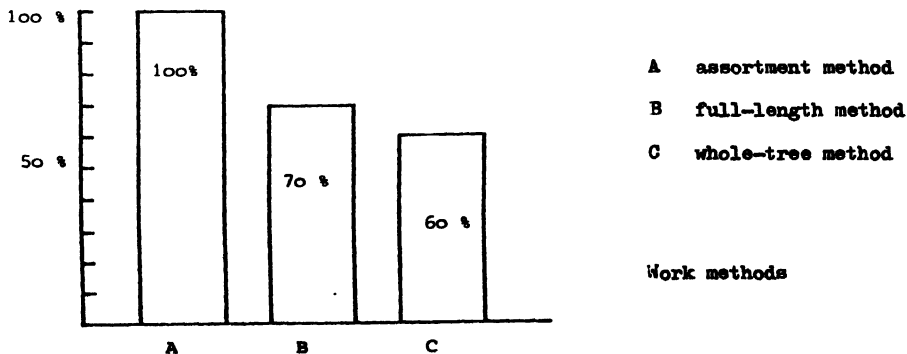
For final cuts and an average log diameter of 30 cm, production costs (wages, machinery, social insurance contributions) for partly mechanized wood harvesting in terrain accessible by skidders can be roughly estimated to be as follows:

38% of total cost for felling and log preparation  
62% of total cost for skidding

For cable logging the ratios are as follows:

35% of total cost for felling and log preparation  
65% of total cost for logging.

For final cuts, and assuming an average log mid-diameter of about 30 cm, a comparison between the assortment method and the full-length method shows that the latter is about 30 to 35% cheaper. A further cost reduction of about 5 to 10% can be achieved when the whole-tree method is used, so that approximately 40% of the costs can be saved (provided that the methods are used only if optimum conditions prevail).



Production costs in % of three different work methods applied in cable terrain

A cost comparison between skidder terrain and cable terrain shows beyond any doubt that costs for logging one cubic metre of timber are always higher for cable extraction than for skidding. Cost savings due to a change-over to another method and an improvement of technologies (that is, planning and organization) become greater with increasingly difficult conditions (also in cable terrain).

A comparison of the assortment method and the full-length method (full utilization of equipment), using a practical example, is shown below:

Assortment method using a  
conventional sledge mounted yarder

Full-length method using a truck  
mounted mobile tower yarder

A.S. <sup>1/</sup>	100.-
A.S.	120.-
A.S.	36.-

Felling and log preparation

Setting up cable system and  
cable yarding

Machinery costs

30 m<sup>3</sup>

daily output

4 500 m<sup>3</sup>

annual output

10 years

expected lifetime of machine

150 working days/year

extent of machine use

A.S.	75.-
A.S.	45.-
A.S.	54.-

80 m<sup>3</sup>

12 000 m<sup>3</sup>

10 years

150 working days/year

In the example, A.S. 82, or 32% of the extraction costs, are saved when the full-length method is used instead of the assortment method (full-length method: A.S. 174; assortment method: A.S. 256).

In thinning operations costs can be reduced only in some instances and not as significantly as in final cuttings.

The law of piece-meal and the difficulty involved in logging without causing damage to the felled trees make the mechanization of thinning operations through improved working methods difficult. Here, the assortment method plays quite a different role from that in final cutting and represents a very useful method, particularly in first-time thinnings.

In thinnings, the whole-tree method is economic only if log mid-diameters are above 13 cm. As is the case with the full-length method, it is not only difficult to log the full-length trees without causing damage to the remaining stand, but it is also a given fact that costs will soar when certain common working operations are carried out.

In cable-logging terrain, production costs for thinnings are also higher than in skidder terrain.

The following detailed cost comparison, which was compiled on the basis of work studies carried out under very specific conditions, shows the various relationships.

<sup>1/</sup> A.S. = Austrian Shilling

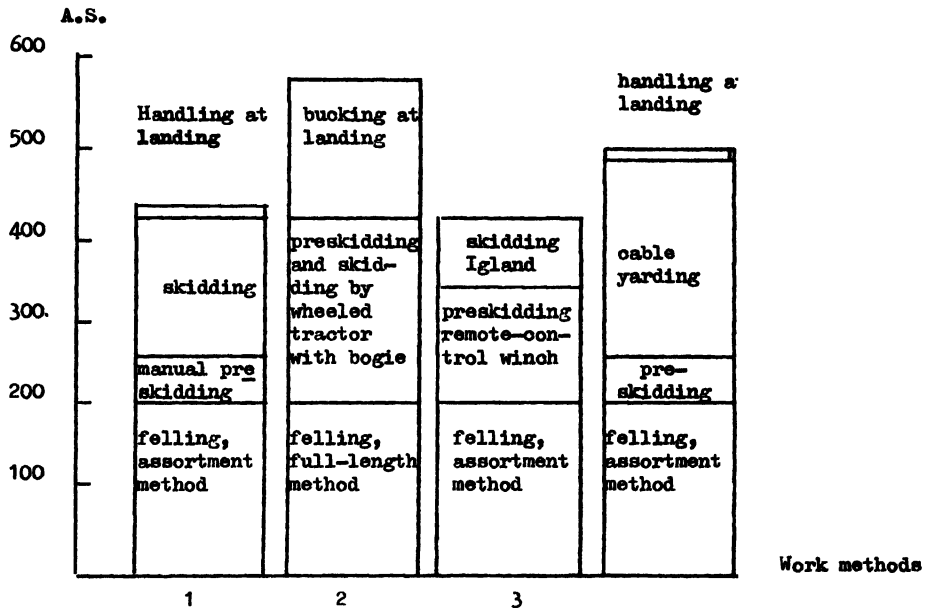


Fig. 5 Cost comparison  
(assortment method versus full-length method)

- Work methods and 2: Power-saw felling and delimbing  
Manual preskidding of small-diameter assortments  
Preskidding of large-diameter wood and poles by cable  
For prelogging and logging: Steyr wheeled tractor with bogie
- Work method 3: Power-saw felling and delimbing  
Prelogging by remote-control winch and skid pan  
Logging by Steyr wheeled tractor and Igland trailer with loading crane
- Work method 4: Power-saw felling and delimbing  
Manual prelogging to cable corridor  
Logging by Steyr tractor with K 300 mobile tower cable crane attachment.

**Assumptions:**

The above cost analysis is based on the assumption that hand-tools and equipment are company-owned. Workers were employed by the company.

- Average wood diameter - 11 cm
- Average logging distance for skidder operation approx. 200 m
- Average logging distance for cable crane operation approx. 150 m
- Average distance for prelogging by remote control winch 30 m

Cost variations arise as a matter of course from the thinning intensity, quantity of timber per skidding track, variations of the middle diameter and other factors.

The logging operations in the above-mentioned examples were carried out very carefully. The number of damaged trees was about 2% of the total tree number.

WORK METHODS	TIME INPUT %	COSTS %
full-length method by wheeled tractor and bogie	100	100
assortment method by wheeled tractor and bogie	76	74
assortment method by remote-controlled winch, wheeled tractor, Igland trailer, loading crane	62	71
whole-tree method by processor, remote-controlled winch, skidder	47	67

Fig. 6 Time input and costs in % of different work methods



Steyr-Csa processor 705 at work delimbing and bucking (Photo: E. Pestal)

## WORK ORGANIZATION IN WOOD HARVESTING

by

Othmar Frauenholz  
Forstliche Ausbildungsstätte Ort <sup>1/</sup>

The purpose of work organization is to plan the best use of available labour, machinery and techniques in production in accordance with the specific task assigned.

<u>Measures</u>	<u>Effects</u>
Detailed planning	- Optimum use of machinery and equipment
Felling sequence	- Safe and efficient work
Determination of the size of the work crew	- Economic efficiency
Making work sites safe	- Lower work load
Organization of working hours	- Qualified work and high efficiency
Arrangement of work breaks	- Mutual satisfaction of employer and employee
Positive follow-up	- Valuable for future projects

The purpose of planning and the opening up of a site in detail is to develop working conditions which guarantee the best use of labour and equipment on the one hand and the careful treatment of the growing stock on the other.

For the employee, detailed planning means organization and control of the work to be performed, which in turn results in safe working conditions, minimum physical stress, and efficient work.

A further advantage of detailed planning is that it results in the efficient use of the machinery and equipment provided for opening up the site. It also means that the operations will not entail additional dangers to man, machinery and equipment, and the forest itself.

Factors in opening up a site which should be carefully planned are the following: skidding trails and tracks, skidding tracks in connection with cable routes and cable crane corridors.

### Skidding trails

These are earth roads which can be constructed at minimum cost. The layout and width of this type of road, which has no surfacing, are determined by the skidding equipment used. Heavy equipment (high horsepower rating) permits the laying out of steep skidding trails. The decisive factor when planning skidding trails is its erosional impact. The use of light skidding equipment requires routing over flat terrain. If agricultural tractors are used, the gradient should not exceed 25 percent.

<sup>1/</sup> Forestry Training Centre Ort, Austria.

#### Minimum width of skidding trails

Skidding trails should have a minimum width of 2.5 - 3.0 m (safety, log gathering, fast transport). Planned as supplementary roads of the forest road network, skidding trails and tracks should provide for skidding on wide slopes which are accessible by truck. The logs are transported to the skidding trail either via the track, by means of uphill cable logging, or downhill by means of the alpine peavie.

#### Spacing of skidding trails

Depending on terrain conditions, the spacing of the skidding trails should range from 100 to 200 m.

#### Skidding tracks

These are natural corridors leading through the stand. Their use is restricted to certain forest vehicles. It is usually necessary to remove individual trees in order to render the track accessible. The forest floor serves as the road surface.

When tracks are selected, the topographical conditions should be taken into account. Good accessibility should be the final goal.

#### Width of tracks

Therefore, tracks should usually be laid out as straight as possible. The average width ranges from 2.5 to 3.0 m (vehicle width plus 1 m).

#### Gradient

On sloping terrain the track runs with the gradient. Cross-inclinations of the roadway should be avoided. If necessary, bends should be adjusted to the maximum length of timber to be skidded.

Skidding tracks should join the forest roads or landings at the most acute angle possible. Planners must take into account the space that skidding vehicles require for turning.

#### Spacing of tracks

On account of the working techniques applied the spacing of tracks should be as narrow as possible. In young stands the tracks should be planned at a distance of 15-20 m. Depending on terrain conditions the distance may vary by a few metres. It should not be determined without taking into account natural conditions.

#### Tracks in connection with cable routes

If the site is exposed to wind, if late thinnings are carried out in old stands or if the forest floor is hardly accessible, the track distance may vary depending on terrain conditions. In special cases it may come to as much as 100 m. However, if the track spacing is as wide as this, the remaining areas will have to be opened up by cable. In this case the economic utilization of the forest may be reduced for the benefit of stand protection. The full economic potential cannot be reached when the forest is hardly accessible (swamp, big rocks).

#### Spacing of cable routes

In such cases the spacing of cable routes may range from 5 to 10 m. The direction of the cable is determined by the topography of the terrain, the machine used for cable logging, the sequence of operations, and the type of cross-cutting required.

### Cable routes

As a rule, in steep terrain the cable line runs with the gradient until it joins a skidding trail or forest road at an angle of 90°. If the gradient is smaller, individual cables may radiate from a suitable landing, which may be highly advantageous. Depending on the length of timber to be extracted and its further handling, the cable will run either in a direction vertical to the track (with skidding and cross-cutting of logs at the track) or at an acute angle to it, if longer assortments or whole trees are required.

### Cable corridors

The shape, length and spacing of cable corridors are determined by the terrain, the equipment used and the working technique selected.

When cable corridors are planned it is especially important that the entire sequence of wood harvesting operations is kept in mind and that a clear decision is made on the measures relating to the protection and best economic utilization of the forest.

### Detailed plan for opening up

1. Determination of the section to be opened up (on the map and in the field).
2. Determination of the direction of timber extraction.
3. Provisional determination of extraction limits (starting and end points).
4. Repeated reconnaissance of the area to be opened up and choice of the best means for the most complete extraction with due regard for existing roads.
5. Determination of the extraction method to be used (skidding trails, tracks, cable routes and corridors).
6. Locating landings and processing sites.
7. Marking of tracks, cable routes, etcetera (marking of the trees to be felled or used).
8. Decision on whether the butt ends or the tops of the log should face the direction of extraction.
9. Determination of the felling direction.

### Considerations for optimum skidding

1. Damage to the stand should be kept to a minimum.
2. Skidding should not cause subsequent erosion damage.
3. The workers should not be subjected to excessive stress or exposed to special dangers in the course of skidding operations.
4. Skidding should be possible at any time of the year. The condition of the timber (bark or branch stubs in contact with the ground) should not hamper skidding.
5. When the skidding system is selected, the size of logs required is a determining factor.
6. Skidding costs should be kept as low as possible; however, these have to be considered in relation to total logging costs.

### Felling sequence

The felling sequence should be chosen with consideration to efficiency and human factors. In addition, it should also cause the least possible damage to the forest.

### Determination of the felling sequence and required measures

Consideration should be given to the direction of skidding, determination of the felling direction, determination of the sequence of operations (beginning and continuation of operations).

Furthermore, the felling sequence includes determining the time and place of wood harvesting operations (whether felling and skidding constitute one work cycle or whether all stump area operations are completed before skidding starts, and so on). The sequence of individual operations ranging from felling to cross-cutting is certainly not always the same, and should be arranged in such a way as to ensure safety, efficiency, and protection of the forest. When the felling sequence is determined, these factors should be taken into account.

In general, the selection of the correct size of the work crew is a key decision in the organization of work. The bigger the crew, the greater the danger of personality clashes, and the greater the mutual exposure to danger. With work safety and increased performance in view, the organizers should try to make sure that the crews are as small as possible, that is, that if possible they consist of one man only.

Reduced idle times, less stress for the individual worker, reasonable running periods of power saws, more diversified and dynamic work, and increased safety are the obvious results of such a measure.

By one-man work we mean that the stump area operations are carried out by one man only. The next worker does the same work at a safe distance. The minimum permissible distance is one and a half tree lengths, while the maximum distance is just within earshot. The sequence of operations on the tree is of special economic and ergonomic significance, which should not be ignored by those organizing work. Moreover, the creation of a safe working place, the organization of working time and the arrangement of breaks that take into account the stress to which the worker is exposed, contribute toward both more safety of the individual worker and a higher performance level over long periods. Work can be done effectively only for a certain period. According to studies by Professor Lehmann the best average performance is achieved with a working time of five to seven hours including delay time and short breaks. If wood harvesting lasts eight hours a day the work results are still satisfactory; if the working time is longer, the average performance is considerably reduced due to increasing fatigue. At the same time the work may be done carelessly and with less concentration, which in turn considerably increases the danger of accidents. It has been known for some time that the workload can be considerably reduced and accidents avoided if work is interrupted by short breaks (two to five minutes).

Positive follow-up, permanent training and the provision of suitable tools and equipment should be a permanent concern for those organizing work.

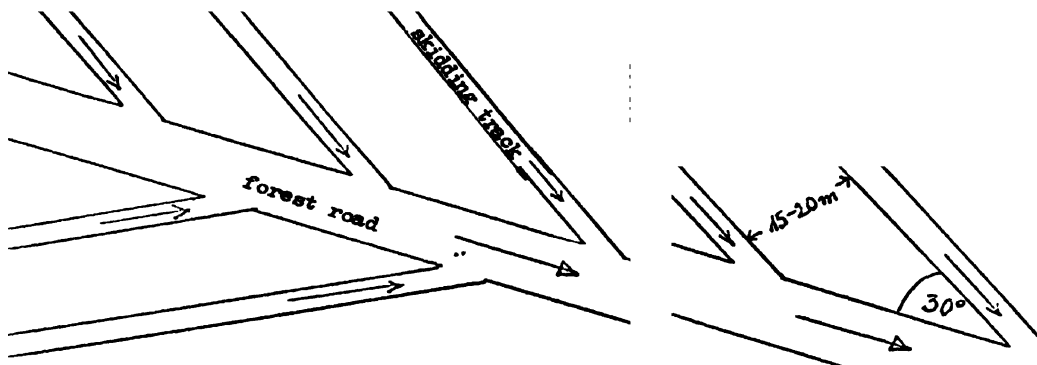
Measures aimed at organizing forest work contribute to increased safety and performance in wood harvesting and are an essential factor in the conservation of the forest and the prevention of stand damage.



ANNEX I

SKIDDING TRACKS

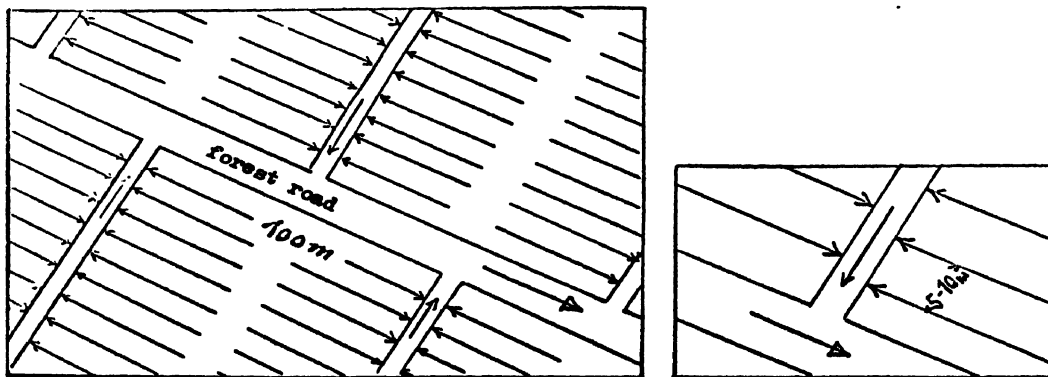
in terrain accessible by wheeled skidder



Skidding tracks join the skidding trails or forest roads at an angle of about 30°. Optimum spacing of skidding tracks is 20 m.

SKIDDING TRACKS

in combination with cable routes



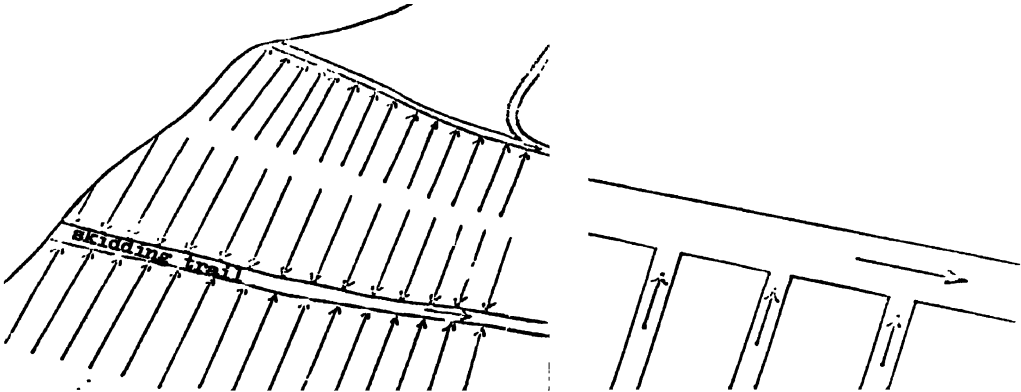
Spacing of skidding tracks max. 100 m.

Width of skidding track max. 4 m.

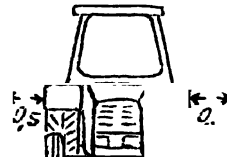
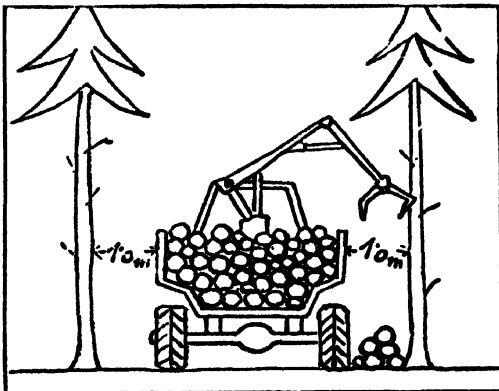
Spacing of cable routes 5 - 10 m.

# SKIDDING TRAILS

in combination with cable routes



- Skidding trails are earth roads constructed at minimum cost
- Spacing of skidding trails 50 to 100 and 200 m.
- Spacing of cable routes about 8 m.
- Width of lateral skidding tracks about 2 m.



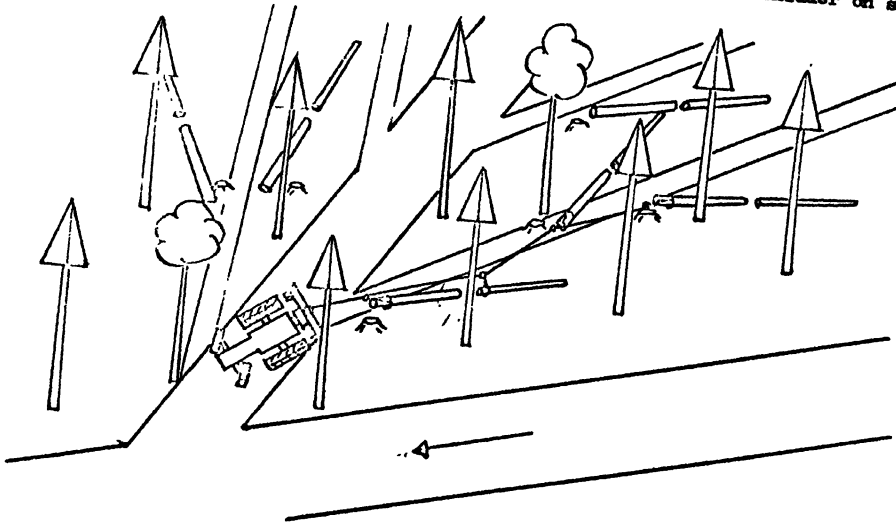
Width of skidding track: width of vehicle + 1m

If possible, tracks should run with the gradient

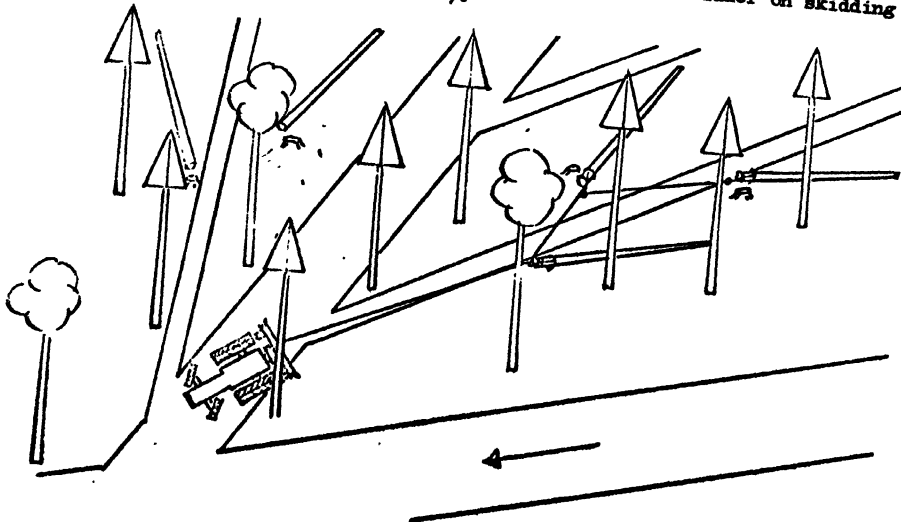
- Width of skidding track for forwarder operations: vehicle width + 2 m.

FELLING SEQUENCE FOR SINGLE TREE FELLING

Downhill operation using the assortment method with skidder on skidding track (low sloping gradient).

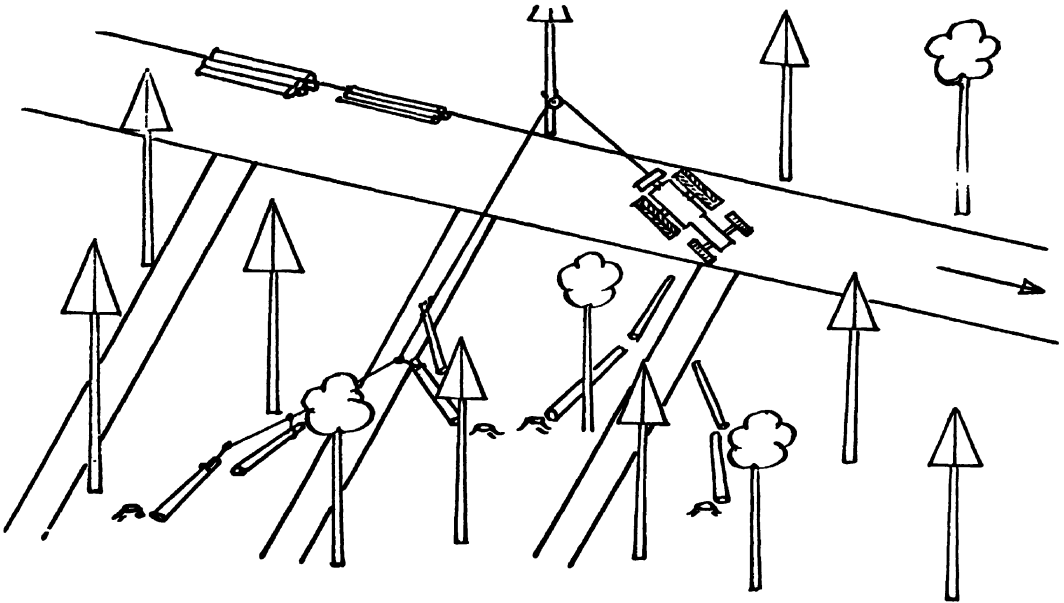


Downhill operation for full-length method with skidder on skidding track (low sloping gradient).

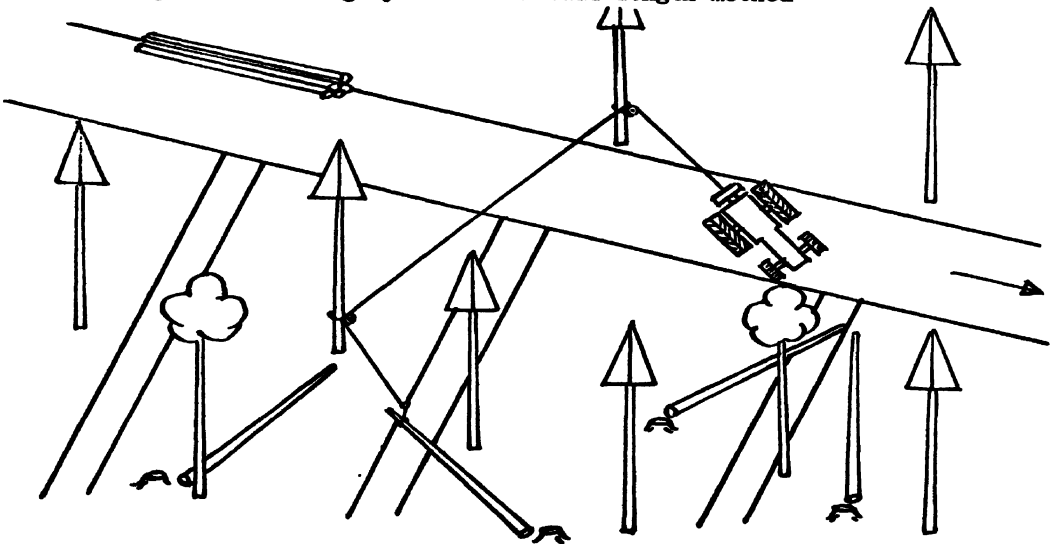


FELLING SEQUENCE FOR SINGLE TREE FELLING

Uphill ground skidding by cable for assortment method.

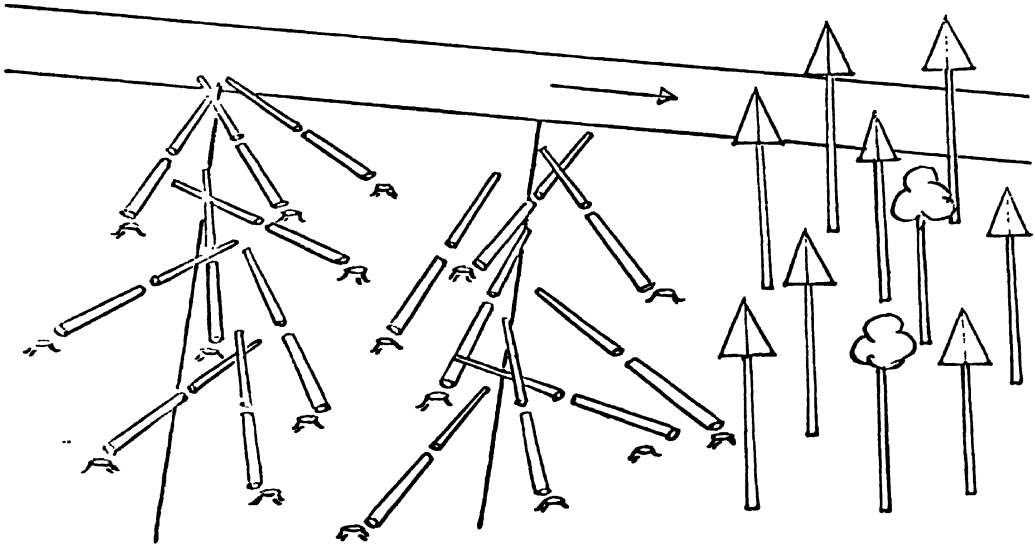


Uphill ground skidding by cable for full-length method

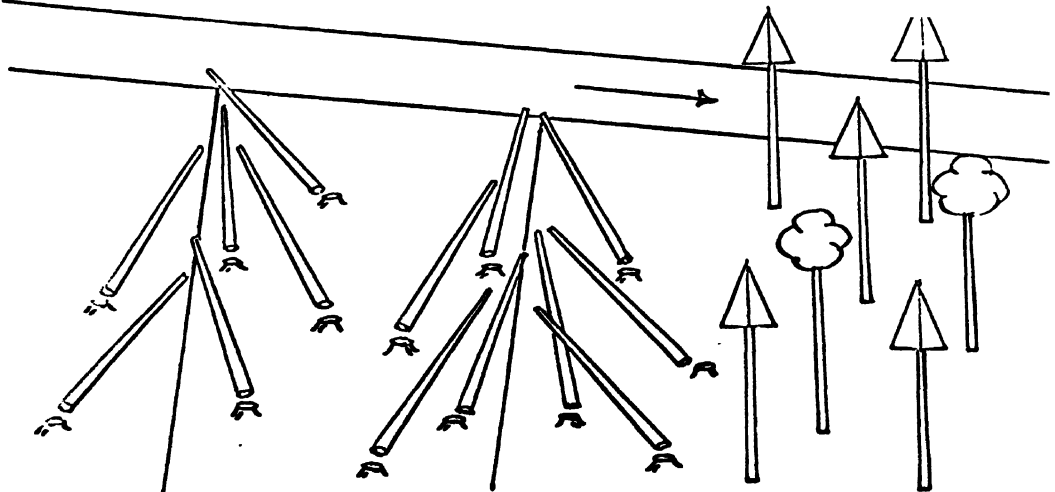


FELLING SEQUENCE FOR STRIP FELLING

Uphill skidding by cable for assortment method

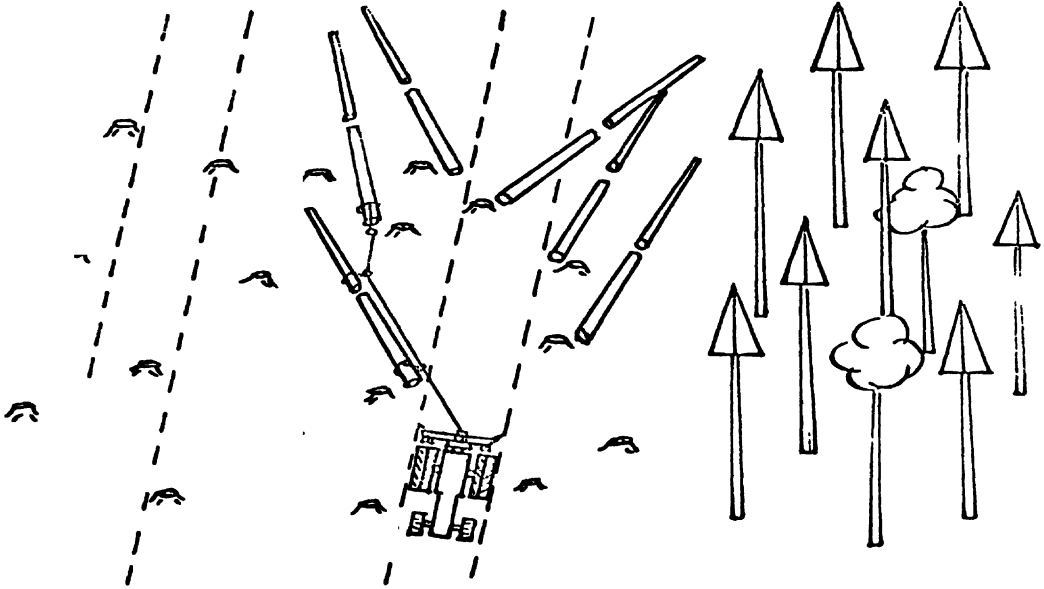


Uphill skidding by cable for full-length method

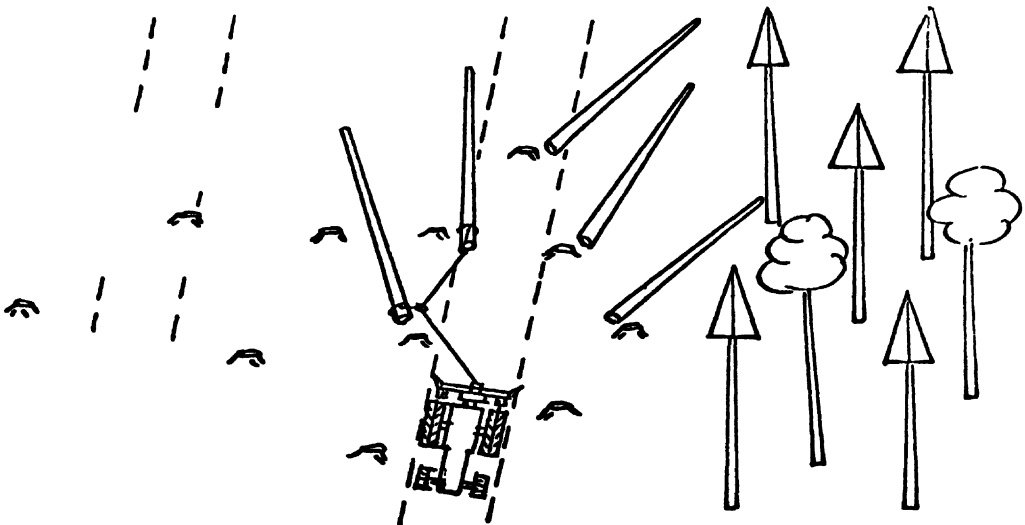


FELLING SEQUENCE FOR STRIP FELLING

Downhill operation by wheeled skidder for assortment method

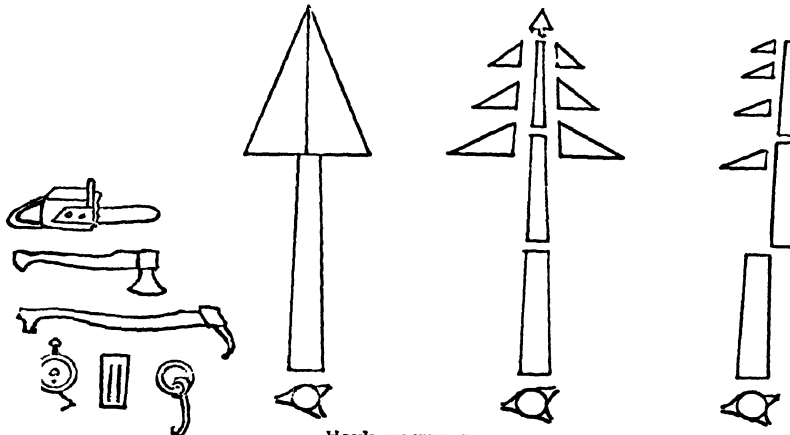


Downhill operation by wheeled skidder for full-length method



ASSORTMENT METHOD  
(Heavy timber)

One worker working on one tree (power saw delimbing)

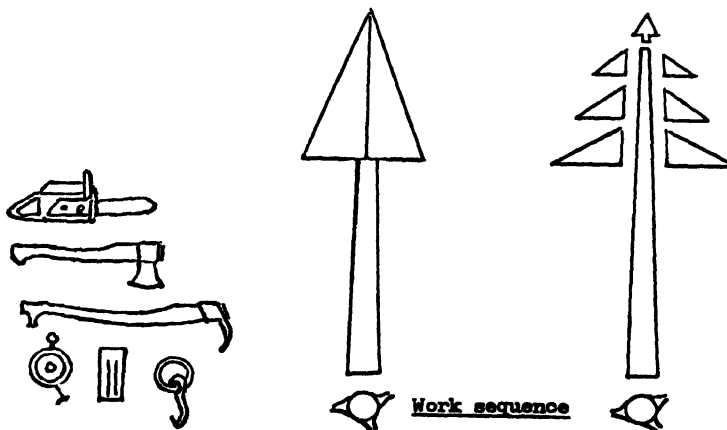


Work sequence

- Tools: Power saw; axe; alpine peavie; rewinding loggers tape; wedge; turning hook
1. Felling
  2. Delimbing on upper side, measuring, sorting
  3. Turning, delimbing on lower side

FULL-LENGTH METHOD  
(Heavy timber)

One worker working on one tree (power saw delimbing)



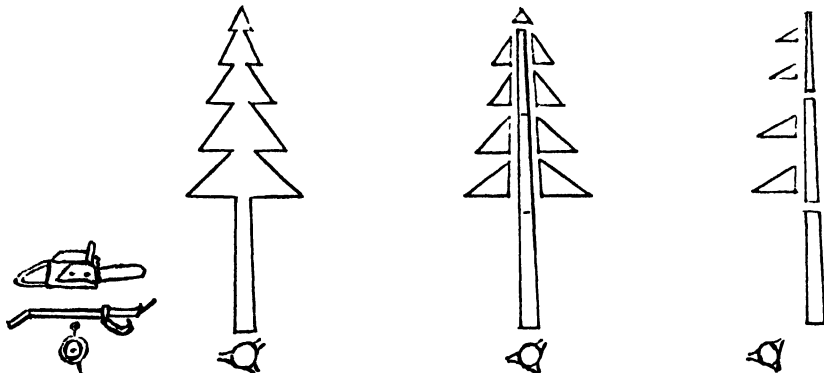
Work sequence

- Tools: Power saw; axe; alpine peavie; rewinding loggers tape; wedge; turning hook
1. Felling
  - Delimbing on upper side, measuring, topping

ASSORTMENT METHOD

(Small diameter wood)

One worker working on one log (delimbing with power saw).



Tools: Power saw,  
cant hook,  
rewinding  
loggers tape

1. Pruning,  
felling

Work sequence

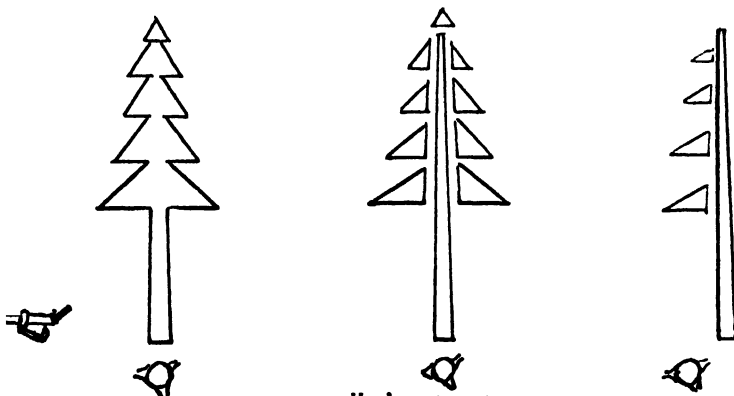
2. Delimbing on upper  
side, marking of  
assortment length

3. Turning,  
delimbing on  
lower side,  
cross-cutting

FULL-LENGTH METHOD

(Small diameter wood)

One worker working on one log (delimbing with power saw).



Tools: power saw,  
cant hook

1. Felling

Work sequence

Delimbing on upper  
side, topping

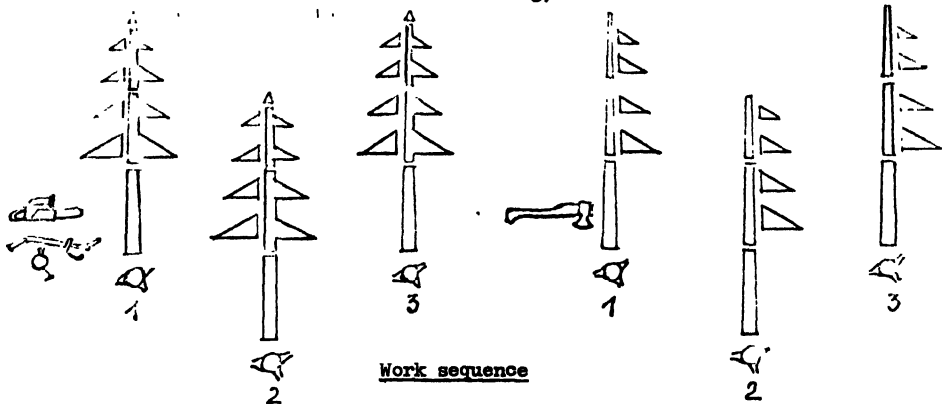
3. Turning, delimbing  
on lower side



# ASSORTMENT METHOD

(Small diameter wood)

One-man cycle operation (power saw and axe delimbing)



Tools: power saw, axe, rewinding loggers tape; cart hook

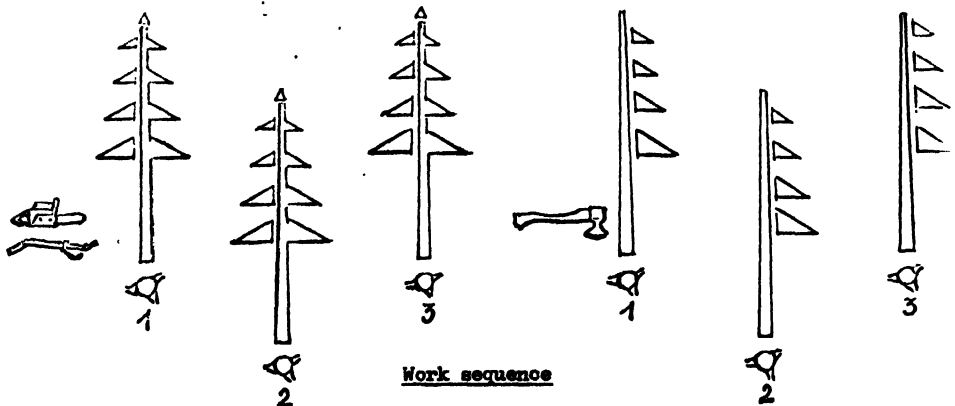
1. Log 1 - 3 Felling, delimbing on left side, measuring, crosscutting

2. Log 1 - 3 final delimbing by axe

# FULL-LENGTH METHOD

(Small diameter wood)

One-man cycle operation (power saw and axe delimbing)

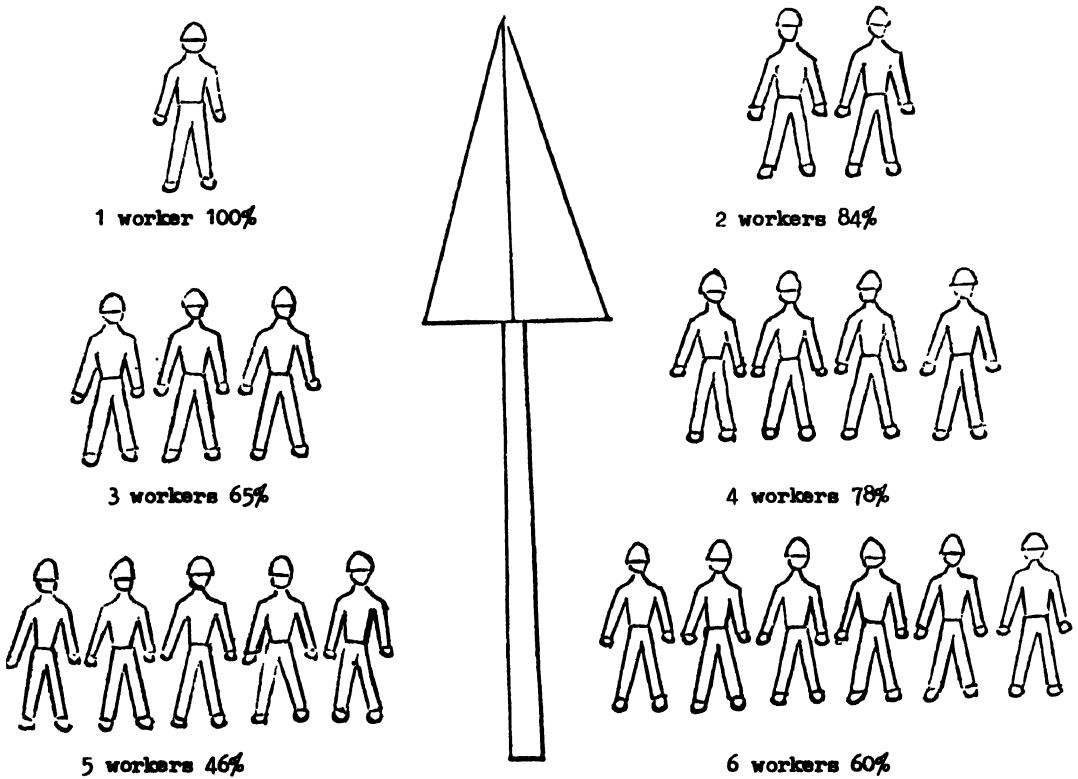


Tools: power saw; axe, cant hook

1. Log 1 - 3 felling, delimbing on left side, topping

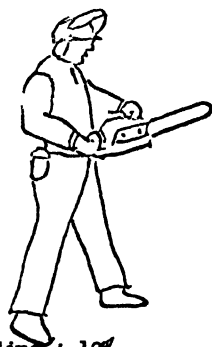
Log 1 - 3 final delimbing by axe

EFFICIENCY OF GROUP WORK

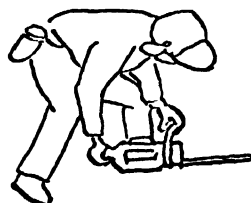


BODY POSITION

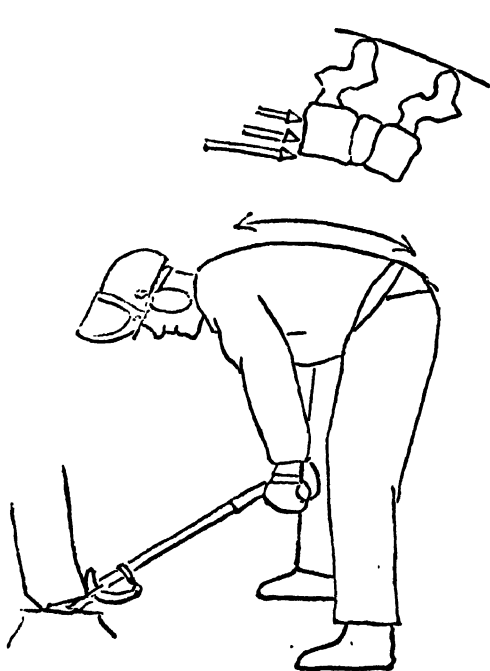
Energy consumption in lying down position = 100%



Standing + 12%



Bending down + 55%



Vibration caused by power saw operation in bent forward position and exposure to heavy workload in lifting with the dorsal spine twisted lead to damage of backbone.



Heavy duty mobile tower cable system (Steyr KSK 16) suitable for the transport of entire trees either downhill or uphill (Photo: M. Pestal)

## EQUIPMENT, TOOLS AND THEIR APPLICATION IN LOGGING

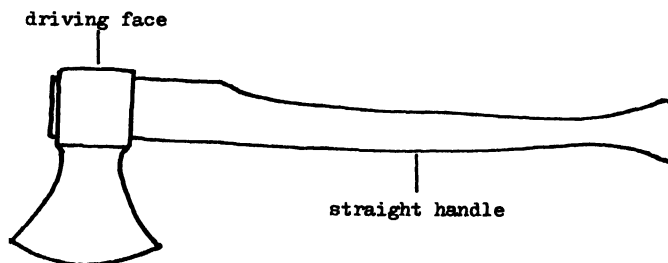
by

O. Frauenholz and E. Feichtinger  
Forstliche Ausbildungsstätte Ort <sup>1/</sup>

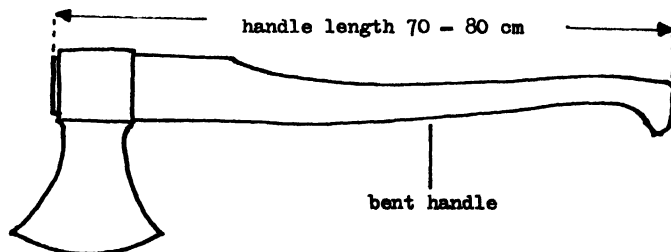
### 1. HAND TOOLS

#### 1.1 Axe

The cutting of large diameter logs and trees, including delimbing, is carried out by chain saws. In Austria the axe is used as a wedge in felling. Its weight should therefore range between 1.20 kg and 1.40 kg, the shape of its handle should be straight.



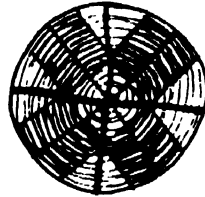
For smallwood, the axe is mainly employed for delimbing. For delimbing the weak smallwood branches, an axe weight of about 1 kg is sufficient. A bent handle ensures a firm grip.



For use in both large and small wood, the overall handle length should be equal to the length of the worker's arm when fingers are bent. In practice this amounts to between 70 and 80 cm.

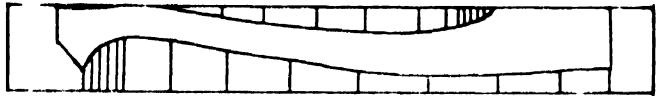
The best handle material is hardwood, such as red beech, white beech, ash, birch and hickory.

The working block is split from a round trunk

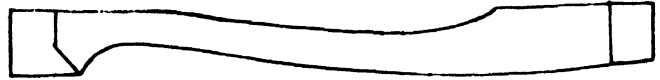


The stages of manufacture of an axe handle

The block is sized, the handle is drawn with a pattern and carved.



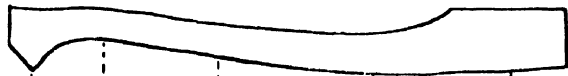
The work piece is squared by chopping or cutting.



The four edges are chamfered to  $\frac{1}{3}$  of faces so that cross-section is now octagonal.



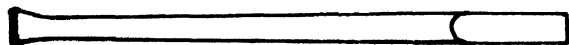
Edges are rounded, the handle is shaped and cut at both ends to the required length.



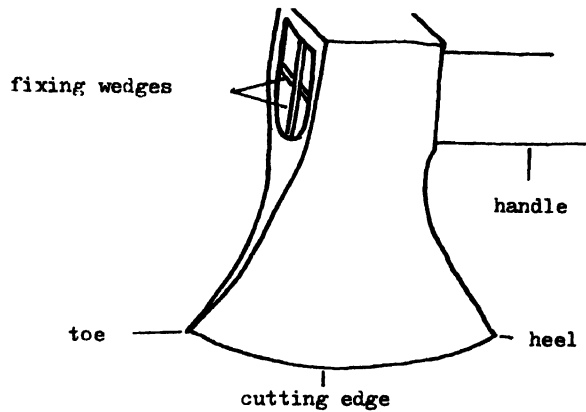
Cross-sections at various points of the handle.



Top view shows tapers before knob and along grip.

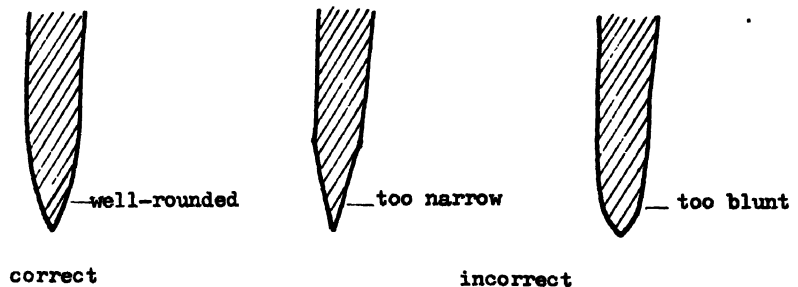


The handle is fixed into the axe by two crossing hardwood wedges.



Sharpening the cutting edge is best done with a wet sharpening stone. The cutting edge's wear resistance depends on the lip angle.

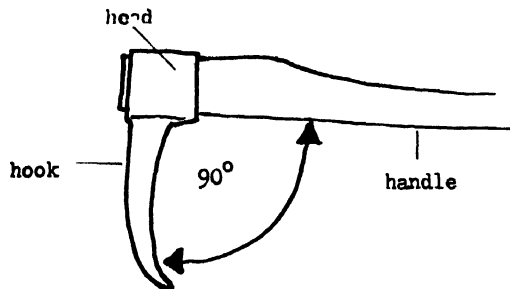
Ground sections of the axe's cutting edge:



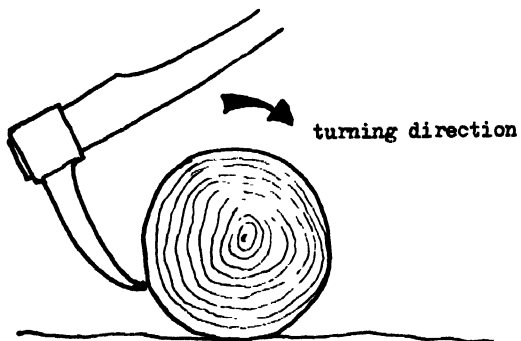
## 1.2 The hookeroon

Loggers use the hookeroon for skidding, turning and lifting stems and logs. There are two forms which are distinguished according to the angle between the handle and the hook:

- (a) straight or German hookeroon; interior angle between handle and hook about  $90^\circ$

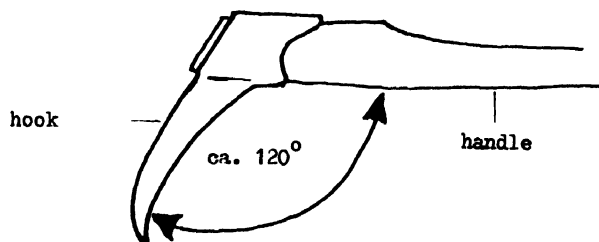


This form is favourable for transporting timber laterally, as e.g. on storing or loading sites. If the head has a reinforced driving face the hookeroon can be used to drive skidding hooks into logs.

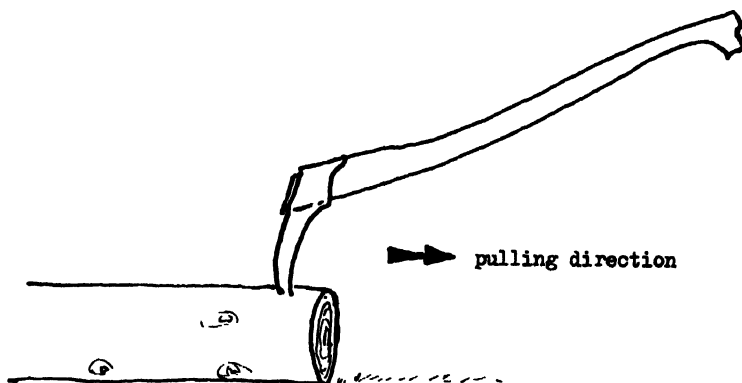




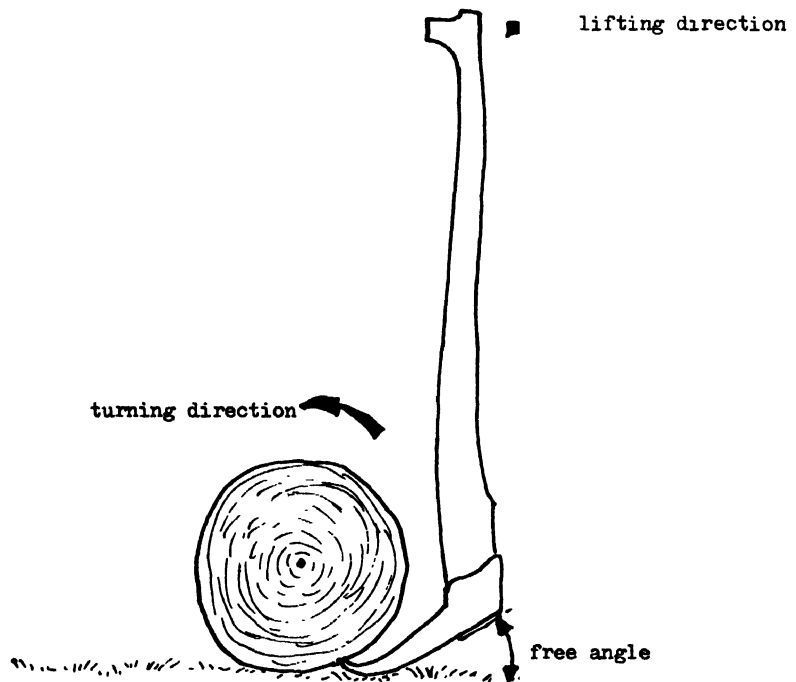
- (b) Krainer or Styrian hookeroon; interior angle between hook and handle about  $120^\circ$



This type is used for longitudinal skidding. When the hook is driven into the log the angle of  $120^\circ$  gives the handle end the ergonomically best position for the worker.



The hookeroon is also employed as a lever for turning operations. The free angle between the head and the ground is an appropriate leverage distance for lifting and turning.

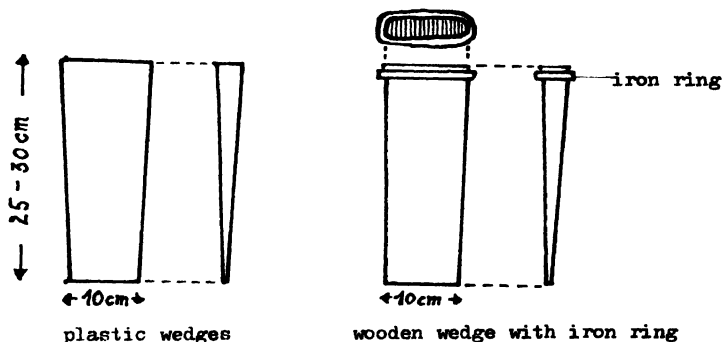


The weight of the hookeroon is from 1.20 kg to 1.40 kg without handle for large size logs and 0.80 to 1 kg for smallwood. The length of the handle depends on the worker's height and is usually from 1.00 to 1.20 m.

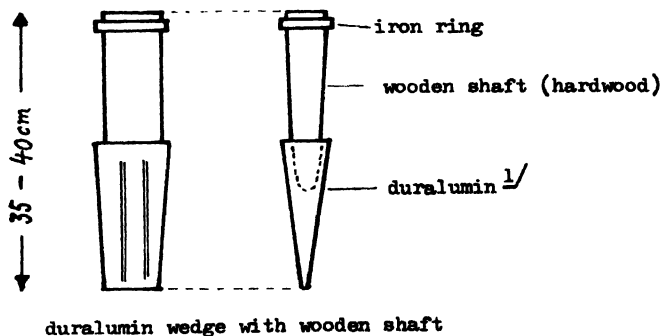
### 1.3 Wedges

#### (a) Felling wedges

For large diameter trees they are used to keep the felling cut open and to wedge the tree down. Wooden and plastic wedges are particularly flat, their length ranges between 25 cm and 30 cm and their width is 10 cm.



For trees that lean backward, wooden or plastic wedges are mostly not strong enough to get the tree down. To increase the opening of the felling cut, wedges with wooden shafts and iron rings are used.



1/ an aluminum alloy

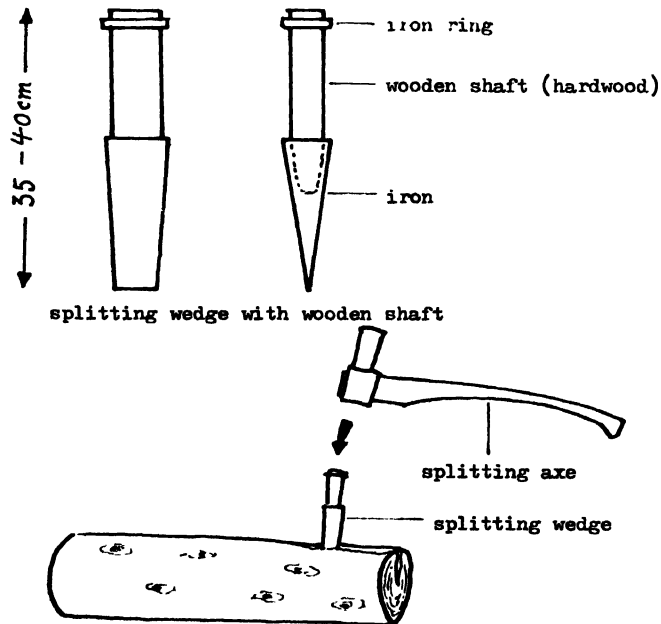
(b) Cutting wedges

The precise cutting techniques of chain saw felling has made this type almost redundant. If hand saws are employed for cross-cutting it is however indispensable to keep the cut open.

It has the same shape as the felling wedge but it is only 10 to 15 cm in length and 5 to 8 cm in width.

(c) Splitting wedges

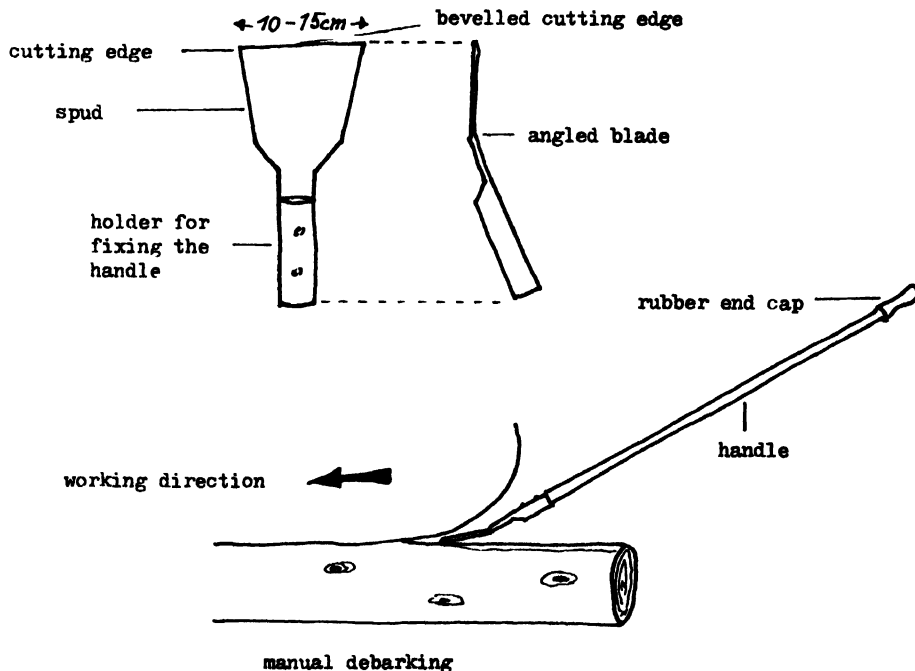
To split 1 metre diameter logs, iron wedges with wooden shafts and iron end-rings are used. In shape and size they resemble duralumin wedges with wooden shafts. A splitting hammer or splitting axe (weight 2.5 to 3.5 kg) is used to drive the splitting wedge.



#### 1.4 Barking spud (bar)

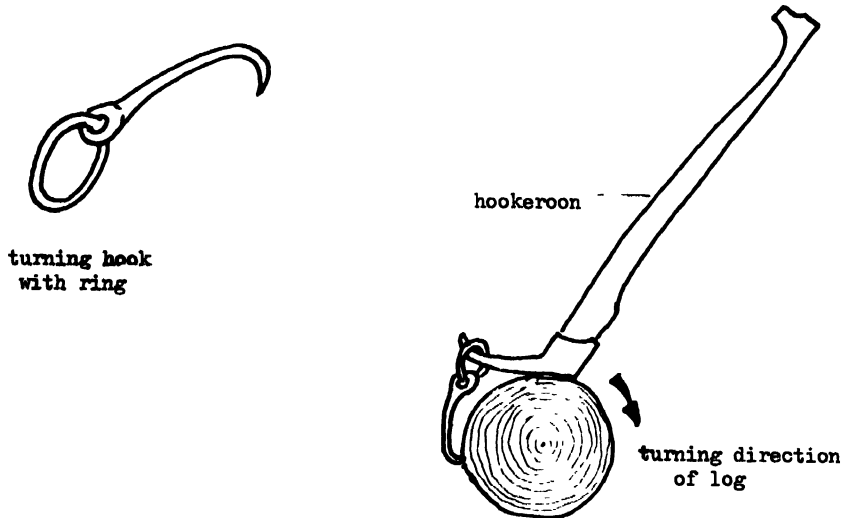
The barking spud serves to remove the bark of large or small wood at the felling site. Manual barking is very rare and only applied in exceptional cases, such as if small timber quantities have to be barked and cross-cut right away because of pest hazards (bark beetle) or if logging has to be carried out by hand because of difficult terrain conditions. The barking spud consists of a steel blade and an opening to hold the handle.

The cutting width of the spud is between 10 and 15 cm, the length of the handle ranges from 1.50 to 2.00 m. The spud should be angled to the handle to avoid bending down while barking.



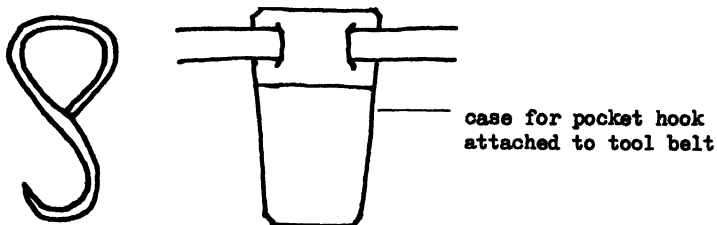
### 1.5 Turning hook with ring

These are used, along with the hookeroon or another lever, to turn logs. This type of turning hook has proved extremely useful for rolling off so-called "hangers" (felled trees that get stuck on neighbouring trees).



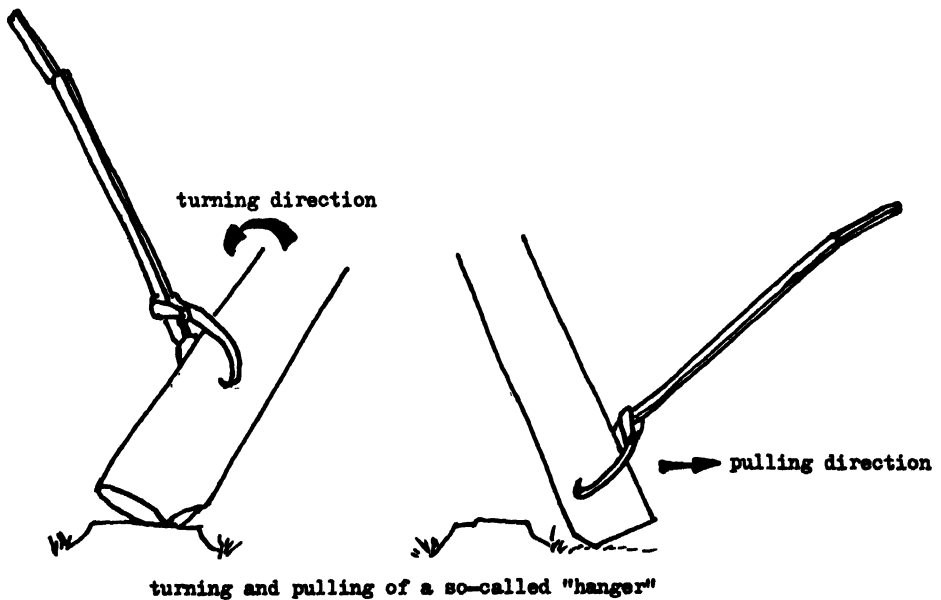
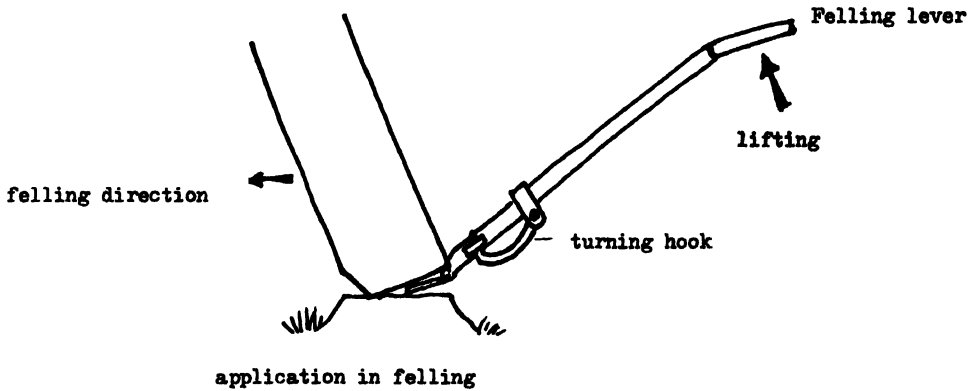
### 1.6 Pocket hooks

This small turning hook is carried in a case (pocket) on the tool belt. It is used for turning, skidding and pulling smaller pieces of wood. For cross-cutting with a chain saw, it can be used instead of the cutting wedge to keep the cut open.



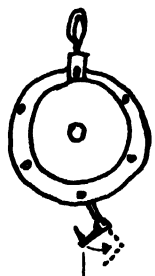
### 1.7 Felling lever

This multi-purpose device replaces the felling wedge in the felling of small and medium diameter trees. For the pulling and turning of logs the turning hook of the felling lever is used.

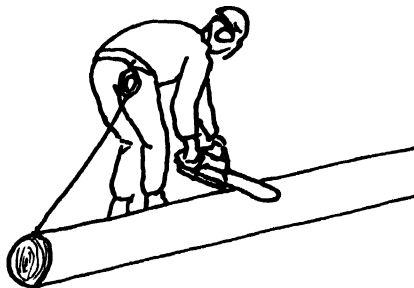


### 1.8 Logger's tape

This is used to measure where to cross-cut felled trees. Most frequent lengths of the logger's tape are 15 m and 25 m. Since the tape is attached to the logger's belt delimbing, measuring, and cross-cutting are carried out in one operation. The tape nail is placed at the point where measuring starts. Moving away releases the plate-spring-tensioned tape.



tape nail with  
plate spring



working with logger's tape

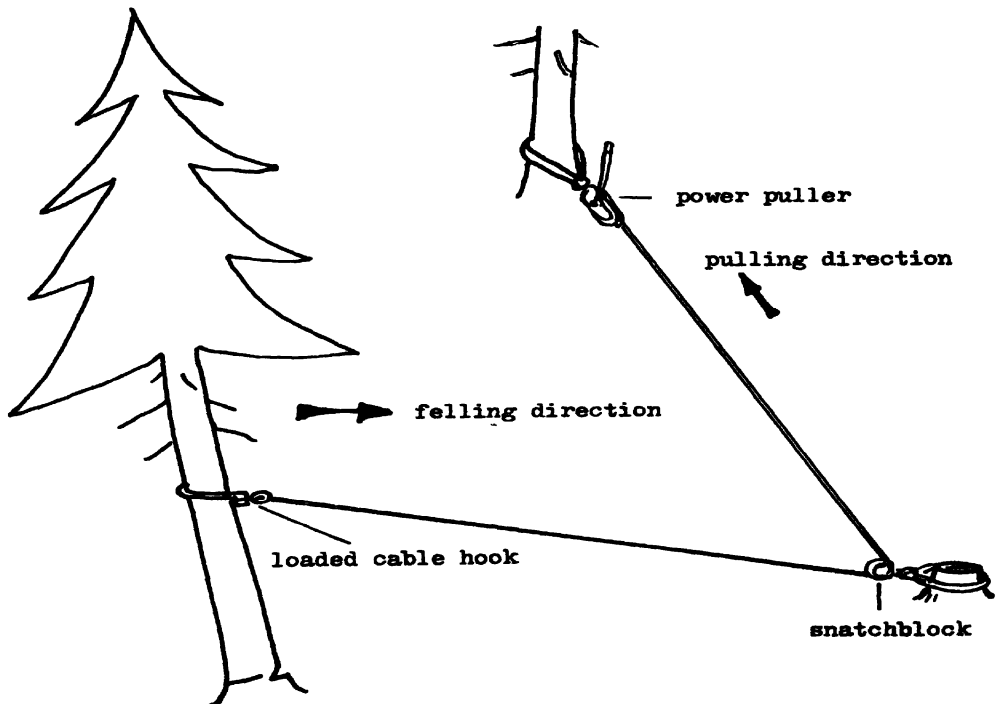
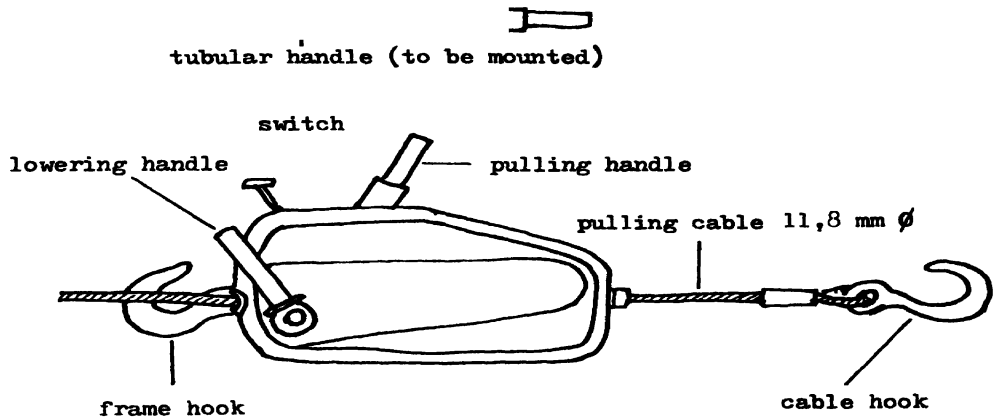
### 1.9 Power puller

This is a manually operated lifting and pulling device with a lifting capacity of 1.5 or 3 tons (various models). In felling, the power puller is used to bring trees down that lean backward and to secure trees in order to prevent them from falling upon dwellings.

The cable length is practically unlimited; for felling, the use of a snatchblock pulley is advisable so that the operator can work outside the foreseen felling direction.



Description of a power puller:

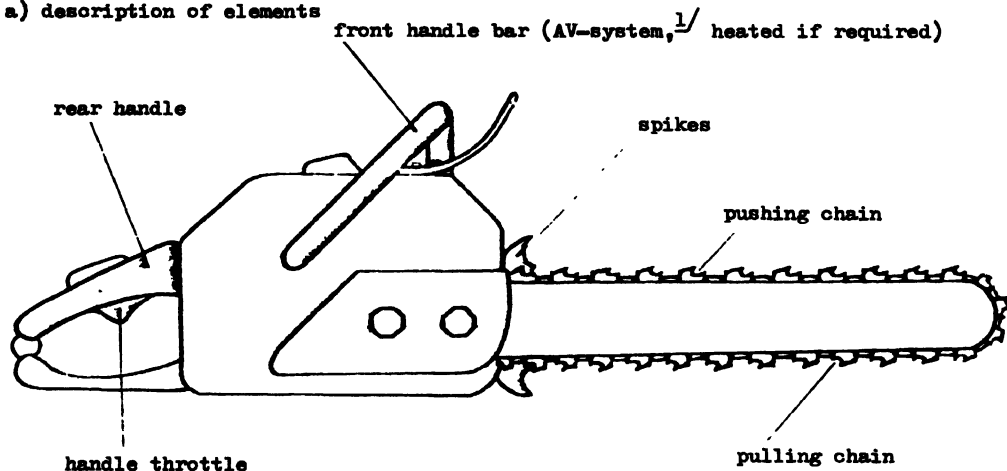


Employment of a power puller for felling a tree leaning backward

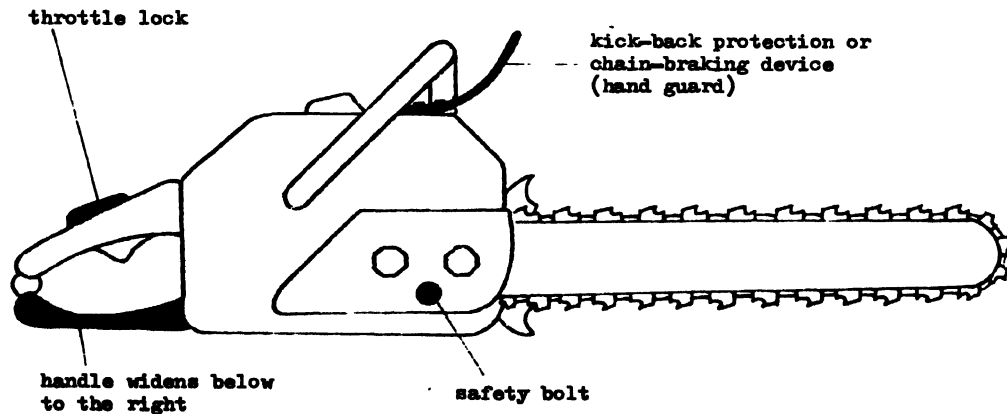
## 2. CHAIN SAWS

### 2.1 Description of the most important elements and safety installations of a chain saw

#### a) description of elements



#### b) safety installations



<sup>1/</sup> Anti-vibration (AV) devices prevent vibration diseases of the hands.

2.2 Weight and power classes of chain saws for large and small diameter wood

Employment	Performance	Weight ready for use	bar length
small wood	1.5 to 2.2 kw (2 - 3 DIN HP)	5 to 7 kg	up to 30 cm
large wood	2.2 to 3.7 kw (3 - 5 DIN HP)	7 to 9 kg	40 to 45 cm
extra large wood and processing site	3.7 to 5.1 kw (5 - 7 DIN HP)	9 to 11 kg	50 to 60 cm

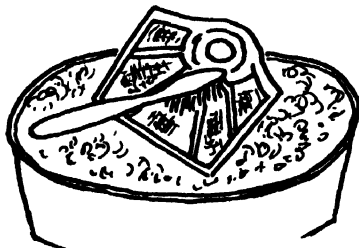
2.3 Service and maintenance

Regular service increases operational safety and the life of the chain saw.  
Required service intervals are:

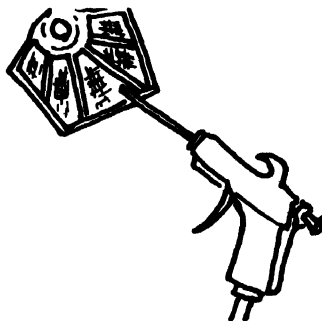
- a) daily
- b) weekly
- c) periodical.

a) daily inspection

air-filter: wash with benzine (gasoline) or washing-up liquid  
diluted with water or clean with compressed air

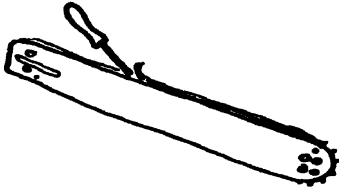


washing with benzine or with  
water and washing-up liquid

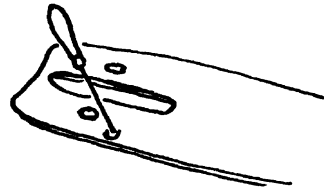


cleaning with compressed air

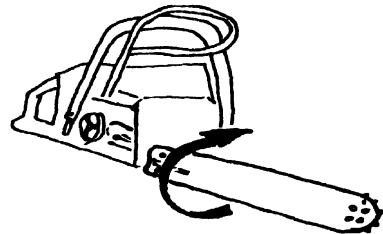
- bar: - clean the guide rail and oil borings  
- lubricate sprocket nose  
- turn and mount the bar



cleaning the guide rail and oil borings



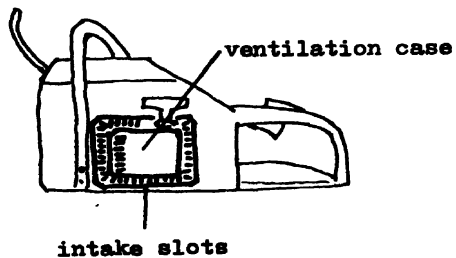
lubricating the sprocket nose



turning and mounting the bar

chain: sharpen saw teeth if required

air intake slots: check slots of ventilation case, clean if necessary



b) weekly inspection

In addition to daily check-up the following items must be inspected every week:

spark plug: - colour control of head:

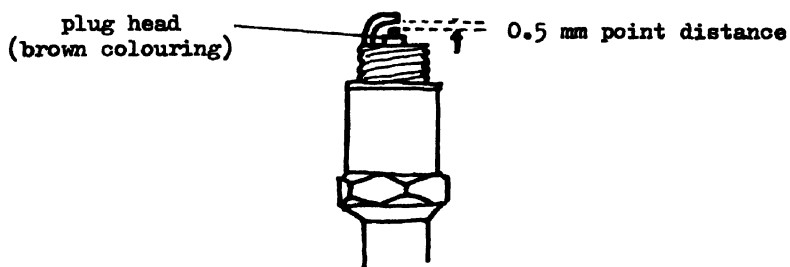
brown - correctly adjusted carburettor

black - adjustment too rich

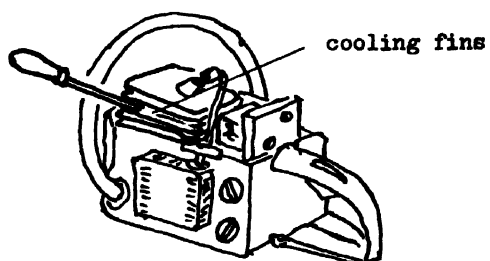
white - adjustment too poor

- point distance control:

distance in all chain saw models is 0.5 mm

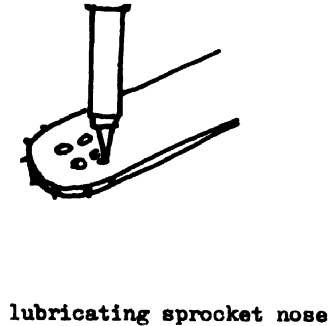
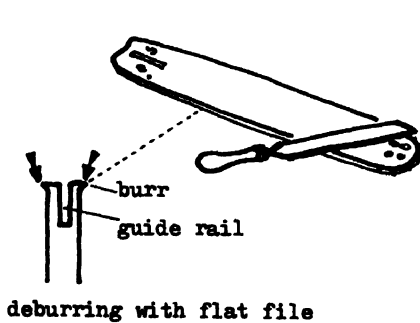


cooling fins at the cylinder: take off cylinder cover and clean cooling fins



cleaning of cooling fins

bar: wear control: - deburr guide rail edges with flat file  
- lubricate sprocket nose and check movability

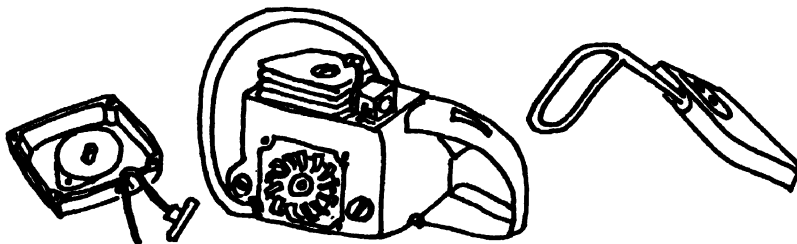


chain: sharpen saw teeth, check length of teeth and depth gauges  
(see description of chain maintenance).

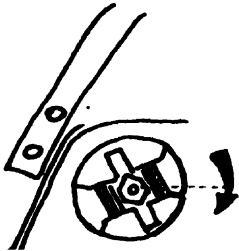
c) periodical inspection

Is carried out after 100 to 150 service hours depending on service time, wear and model. Some manufacturers include maintenance plans in their instructions for use. The following items are added to daily and weekly inspection:

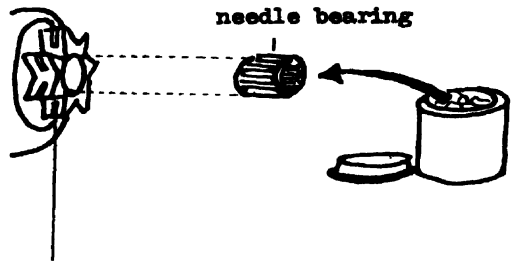
general cleaning: with cold cleanser or benzine



- clutch: - disassemble (left-hand thread opens by right-hand turn)
- check wear on centrifugal weights, tension spring and chain drive wheel
  - clean clutch drum and needle bearing
  - lubricate needle bearing with multi-purpose oil



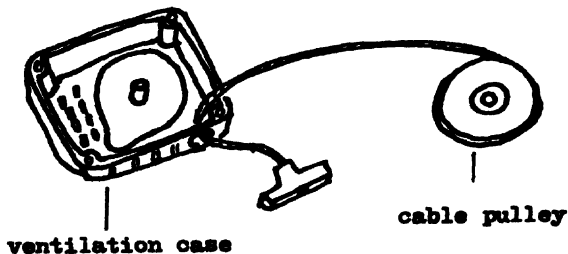
opening of clutch by  
right-hand turn



wear on chain  
drive wheel

oiling the  
needle bearing

- starter: - dismount and disassemble pulley and rewind spring
- clean and oil the rewind spring
  - check starter cable for



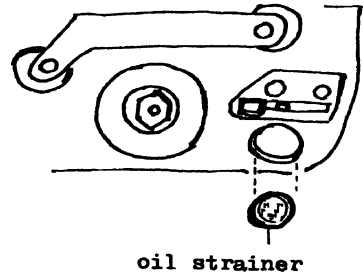
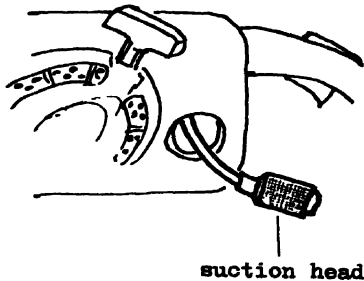
ventilation case

cable pulley



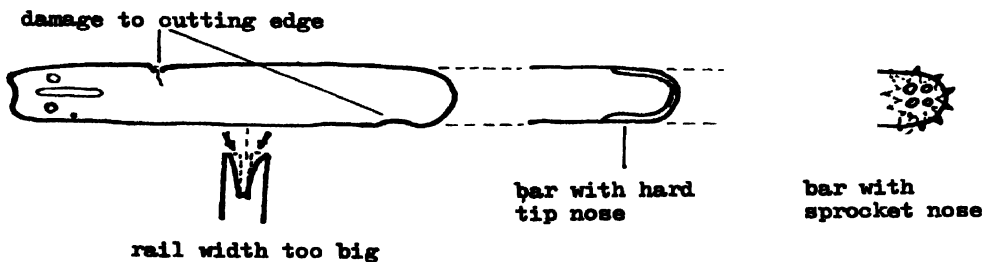
rewind spring  
inside case

- fuel and oil caps: - dismount and clean suction head
- clean fuel and oil caps with benzine
  - if supply line for oil pump contains a strainer, dismount and clean



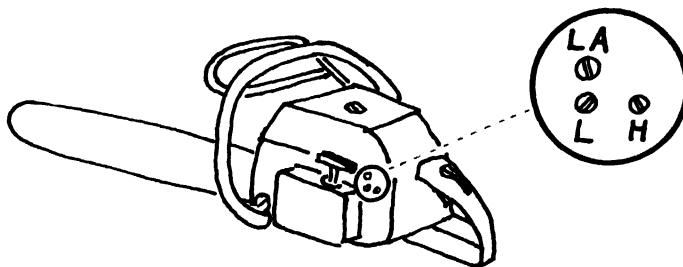
- exhaust: - dismount and clean
- clean cylinder bores of combustion residues

- bar: - check wear on cutting edge of chain
- check rail height and width
  - check hard tip nose of bar or alternatively
  - check and oil sprocket nose of bar





- carburettor: - dismount and disassemble only in case of failure
- compare carburettor adjustment with manufacturers' instructions;
- H - main adjustment screw  
L - idle speed adjustment screw  
LA - idle speed release screw
- before adjusting the carburettor the chain saw must be worked to operational temperature and air-filter and spark plugs must be clean.

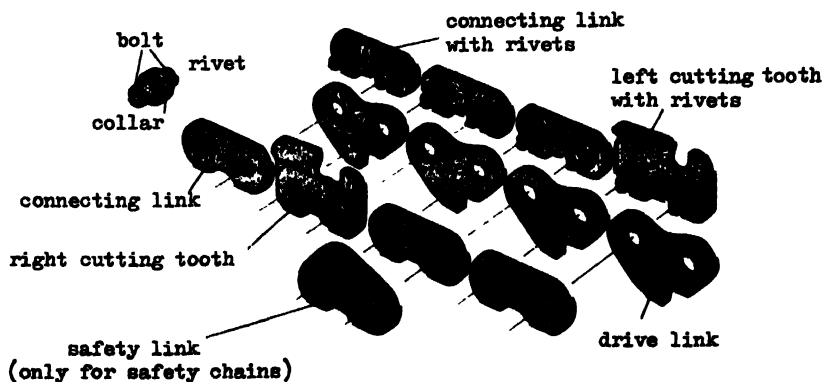


screws for carburettor adjustment

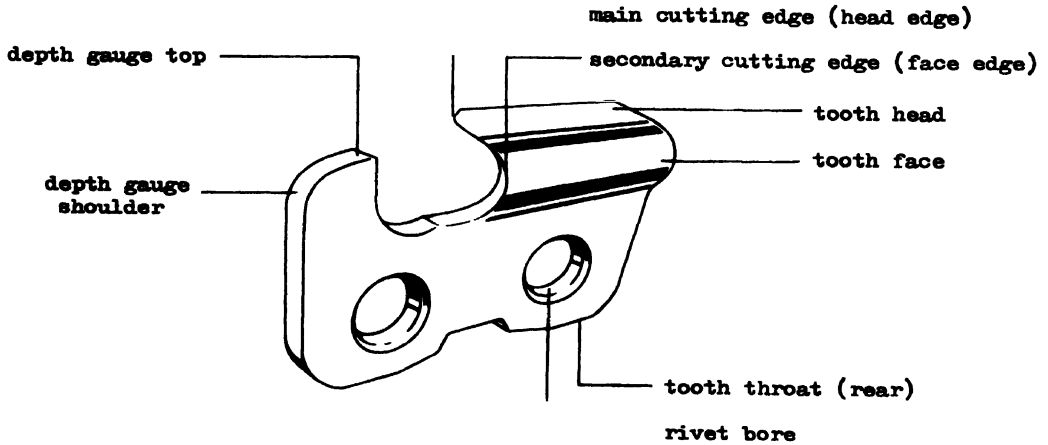
#### 2.4 Power saw - chain maintenance

Proper chain maintenance guarantees good and consistent cutting performance, reduces wear on chain and bar, saves fuel and muscular strength (energy).

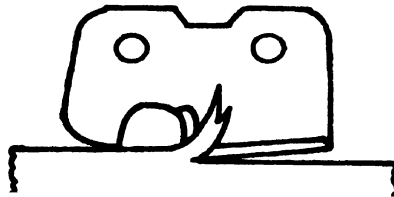
The elements of a power saw chain:



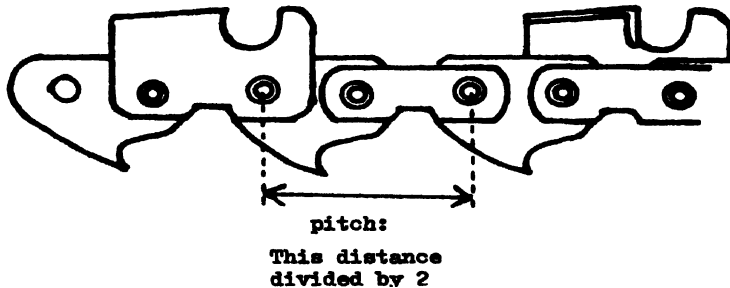
**The cutting tooth**



**The cutting tooth in operation:**



the chain pitch is given in inches (1 inch = 1" = 25.4 mm).



10 links are measured to determine the pitch. The following pitches are available at present:

$\frac{1}{2}$ "	-	12.7 mm
$\frac{7}{16}$ "	-	11.1 mm
.404"	-	10.3 mm
$\frac{3}{8}$ "	-	9.5 mm +)
.354"	-	9.0 mm
.325"	-	8.3 mm +)
$\frac{1}{4}$ "	-	6.4 mm

+) These are presently the most common pitches.

Tooth shapes (cross-sections)



round tooth



semi-chisel tooth



chisel tooth

#### 2.4.1 Maintenance accessories for chains

- hand files



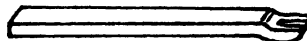
round file



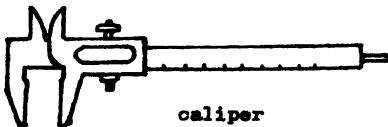
flat file



sharpening scantling

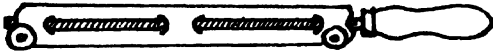


depth gauge filing guide

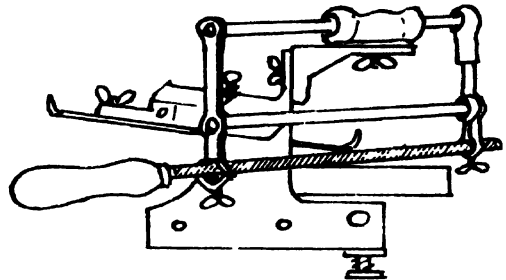


caliper

- filing accessories



filing guide



hand chain sharpener

- electric chain sharpener (used mainly by service shops)

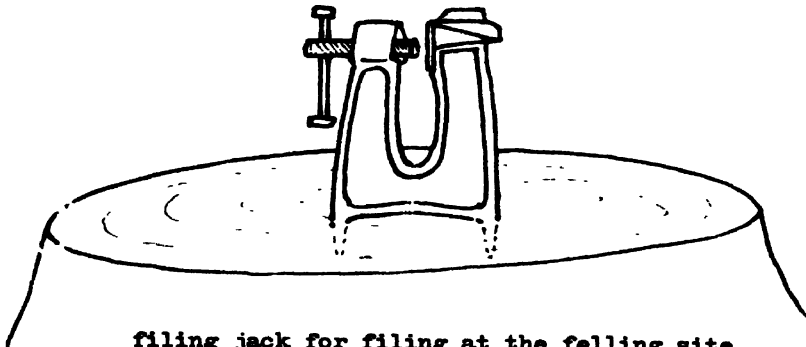
2.4.2 Instructions for maintenance of chain by hand

i) Preparation

Clean the chain to a dry state (until no more lubricant remains on the cutting teeth).

Fix the bar into a filing position (such as: a vise, filing jack for filing at felling site, cut bar into trunk, and the like).

Tension chain if required so that cutting teeth do not give way while filing.



filing jack for filing at the felling site

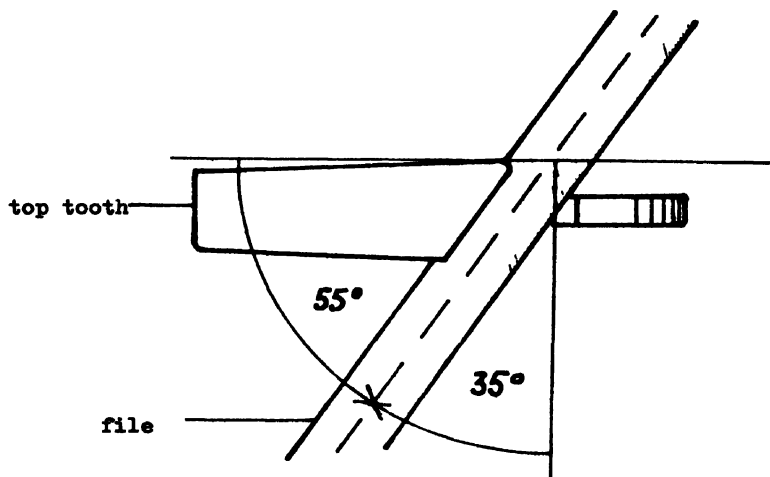
- ii) Choice of correct file diameter  
(depends on chain pitch, tooth height and wear)

pitch (in inches)	file diameter (in inches and mm)
7/16"	1/4" (6.3 mm) from half the tooth length 7/32" (5.5 mm)
.404"	7/32" (5.5 mm) last third of tooth length 3/16" (4.8 mm)
3/8"	7/32" (5.5 mm) from half the tooth length 3/16" (4.8 mm)
.325"	3/16" (4.8 mm)
1/4"	5/32" (4.0 mm) last third 1/8" (3.2 mm)

- iii) Filing the main and secondary cutting edges

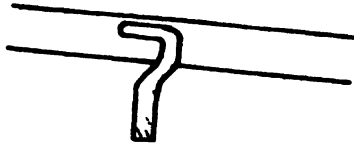
a) filing angle for	softwood	hardwood, frozen softwood and dirty wood
round tooth	55° (35°)	60° (30°)
semi-chisel tooth	55° (35°)	60° (30°)
chisel tooth	60° (30°)	60° (30°)

auxiliary device - sharpening scantling

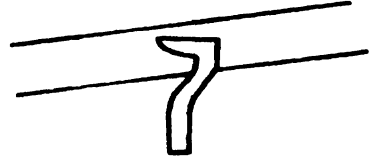


b) filing gradient

when filing round tooth and semi-chisel tooth file runs parallel to back rake



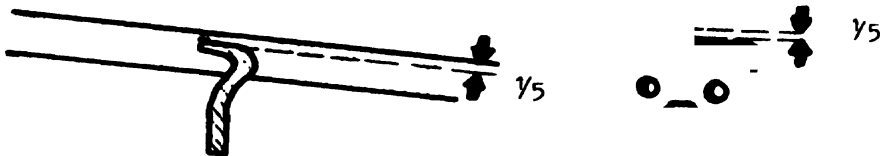
chisel tooth  
10° upward



check: main cutting edge is in line with file.

c) guide height

1/5th of the file's diameter should rise above the top tooth.



check: with round teeth the tooth face forms a right angle with the cutting edge, with semi-chisel teeth it is bearing out by 5° and with chisel-type teeth by up to 10°.

incorrect filing:



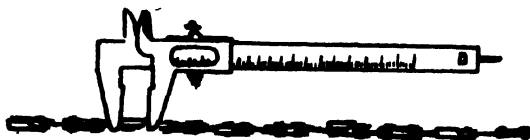
receding tooth face,  
file was led too high



tooth face bearing out  
too much, file was led  
too low

d) tooth length

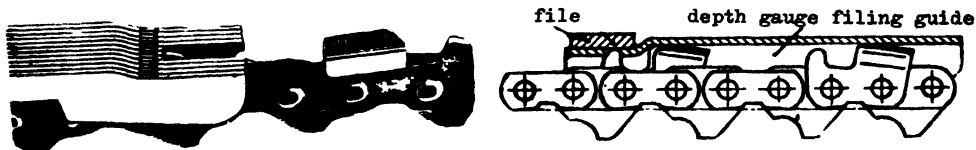
All teeth must have equal length. The caliper is set according to the average length of the shorter teeth.



Consequence: Only teeth of equal length have equal height and equal cutting force. Frequently, the length of right cutting teeth differs from left-hand cutters by which cutting surfaces in the wood become uneven and wear on bar and chain is unilateral.

iv) Maintenance of depth gauges:

Depending on engine capacity, chain speed, guide rail length, wood species and wood condition, depth gauges are by 0.5 mm to 1 mm lower than the main cutting edges. Filing is done by flat file with the help of a depth gauge filing guide.



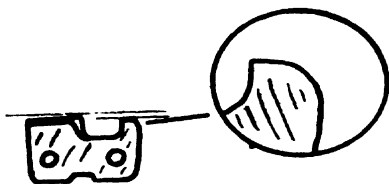
Depth gauge filing guide with recess in the centre (guarantees exact depth gauge heights)



Depth gauges of light and middle weight saw chains are 0.65 mm lower, of heavy-duty saw 0.75 mm lower than the main cutting edges. These figures are reduced by 0.1 mm if timber is hard and frozen.

If required, the front edge is rounded by a flat file without damaging the gauge's even gliding surface and the cutting tooth's main cutting edge.

correct depth gauge shape:



incorrect depth gauge shape:



gliding surface too low and  
not levelled and not rounded  
too high

Consequence: Depth gauges that are too short because they have been filed too low let the cutting teeth enter the wood too deeply thus causing the chain to jerk. Depth gauges that are too high prevent the cutting teeth from entering deeply enough: the cutting pressure has to be increased, cutting performance and wear are affected (wear on the rear cutting tooth throat is extremely high). Depth gauges that are not rounded exert a braking effect on the sole of the gullet, they increase friction and reduce cutting performance. Wear on the front throat of the cutting tooth is too high.

#### 2.4.3 Maintenance by means of file guides and sharpening devices

They are employed according to their respective instructions for use.

Remarks on filing:

- It is important to keep the cutting edge in optimum condition. Do not work with blunt cutting edges.
- Apply both hands to lead the file with moderate lateral pressure and a straight stroke away from you. The lower arm and the file form a straight line.
- Turning the file will not make the edge sharper.
- Lift the file laterally from the filing surface when leading it back.
- By right-hand and left-hand filing the surfaces become more even.
- Good sight and a clamping device at elbow height make filing easier.
- Teeth lengths and depth gauges are usually measured during main chain inspection (after about 5 times of intermediate filing).



Filing depth gauges of safety chains requires filing guides with wider recess.

A slightly receding secondary cutting edge makes the main cutting edge somewhat blunter and more resistant (advantageous when cutting dirty timber).

General remarks:

- File new chains before use, oil well (oil can, additional oiling) and run in at moderate speed. Correct chain tensioning is important.
- If chain is too long, in case of rupture and damage to the links, chain is repaired with spare links.

Auxiliary equipment: flat file, break'n-mend tool, punch and vise.  
The condition of spare links has to be adjusted to the wear degree of the chain.

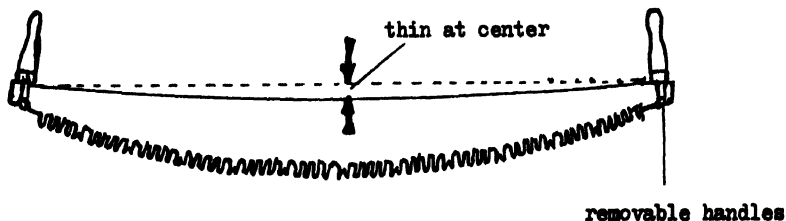
- Before buying a new chain check whether bar, pinion and chain fit together. Ordering information includes chain description, chain length (number of drive links), chain pitch and chain gauge. Sometimes it is sufficient to indicate chain saw make, model and bar length.

3. CROSS-CUT SAWS

3.1 Two-man cross-cut saw

This saw is operated by two workers and used to cut trees/logs with diameters over 30 cm.

For felling large sized trees the saw length should be 1.40 to 1.60 m and the width at center 12 to 14 cm. In order to drive wedges into the cut the saw must be thick at the ends and thin in the center. The handles should be removable so that the saw can be pulled out of the cut even after the wedge is driven in.



There are two types of cross-out saws:

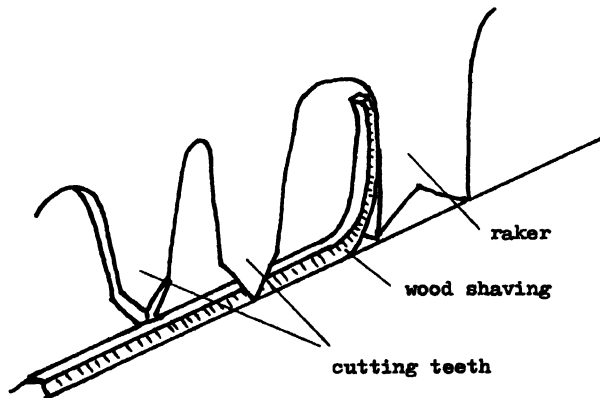
- a) with two cutting teeth to each raker for use on hardwood;
- b) with four cutting teeth to each raker for use on softwood.



Two cutting teeth to each raker

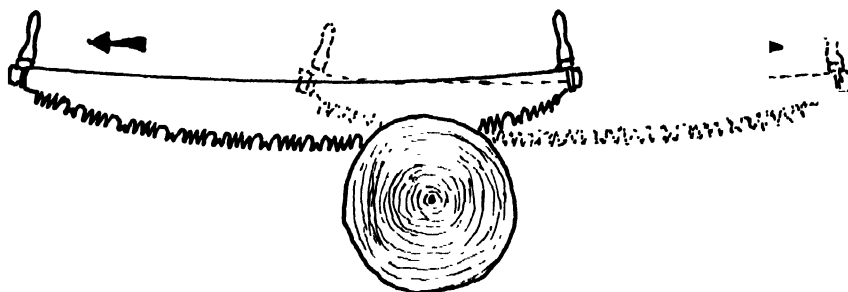
Four cutting teeth to each raker

The cutting teeth sever the wood laterally whereas the raker cuts it at the bottom and removes the shavings from the kerf.



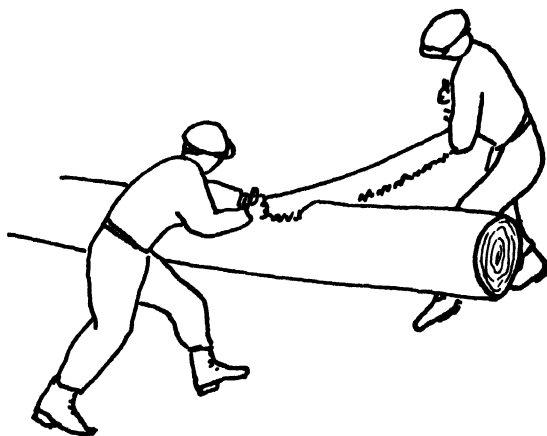
cross-out saw at work

The effectiveness of the cross-cut saw is influenced by such factors as saw stroke, sawing technique and body position. The saw is moved by using straight pushing and pulling strokes while slight pressure is exerted on the blade.

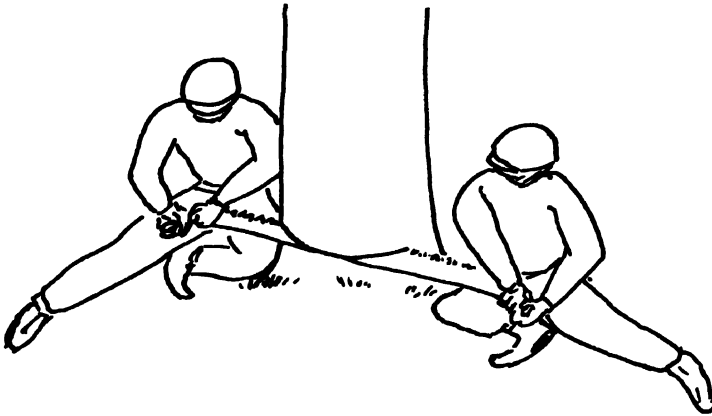


technique of work with cross-cut saw

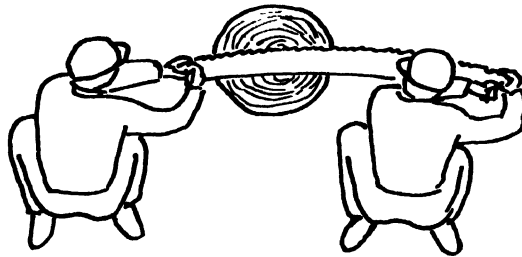
In order to avoid early fatigue the saw must be worked with both hands and an appropriate body position. If standing up is impossible kneeling is advisable (e.g. for felling cuts in flat terrain).



body position in cross-cutting (raised log)



body position for felling cut



body position for felling cut

Maintenance of the cross-cut saw requires the use of the following auxiliary devices:

a) chuck jaws:

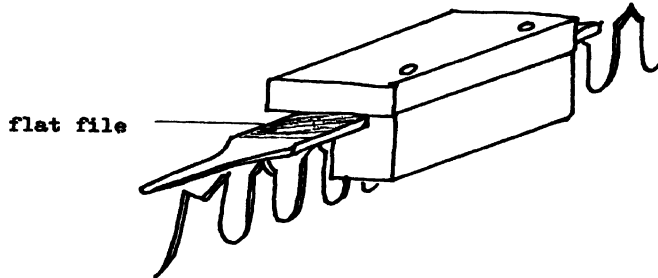
This leaves both hands free for sharpening, swivels around its longitudinal axis and is equipped with a control grid for accurate filing.

control grid



b) tooth top plane:

The flat file fixed to the plane stock files all teeth to an equal height.



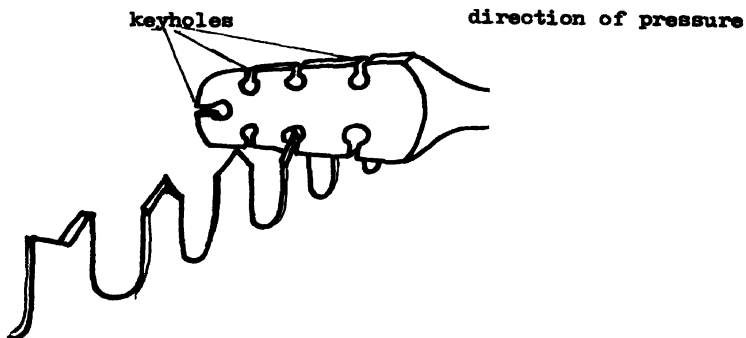
c) flat file

Flat files for sharpening cross-cut saws should be 20 cm long and 2 cm wide. The number of edges per cm should be rather high (20 to 24 cuts per cm).



d) saw set

To avoid jerking of the blade when sawing, alternating cutting teeth are bent outward by a saw set. The saw set has keyholes of various sizes and can be applied to various saws.

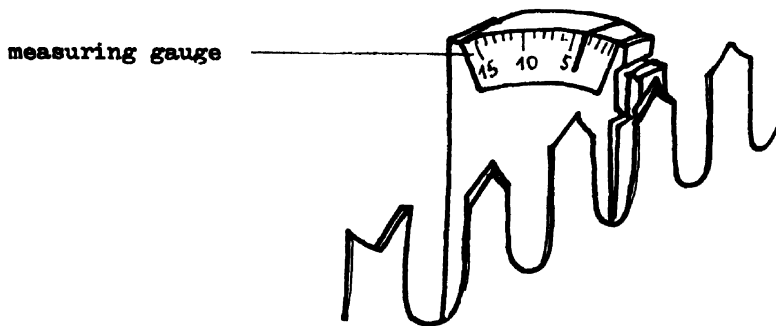


e) saw set gauge

They are used to measure the set width of cutting teeth. The set width amounts to tenth of millimetres so measuring has to be accurate with the gauge tightly attached to the blade.

set width for softwood = 0.5 mm

for hardwood = 0.4 mm

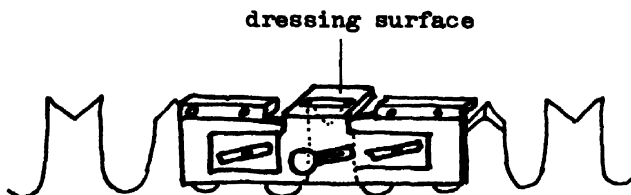


f) dressing tool for rakers

Rakers are some tenths of millimetres shorter than the cutting teeth.

for softwood 0.6 to 0.8 mm shorter

for hardwood 0.4 to 0.6 mm shorter

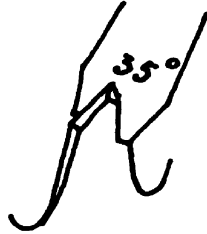


**Sharpening the cross-cut saw:**

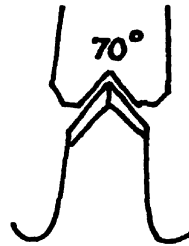
- (i) clamp the saw into the chuck;
- (ii) file the cutting teeth by means of tooth top plane until all teeth have a white top;
- (iii) set the cutting teeth by use of setting gauge and saw set. Setting must be done before the rakers are filed;
- (iv) sharpen the cutting teeth with a flat file;

sharpening angle for hardwood and softwood =  $35^{\circ}$

tooth top angle for hardwood and softwood =  $70^{\circ}$

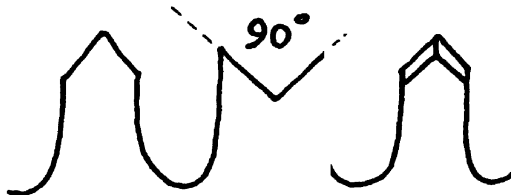


sharpening angle



tooth top angle

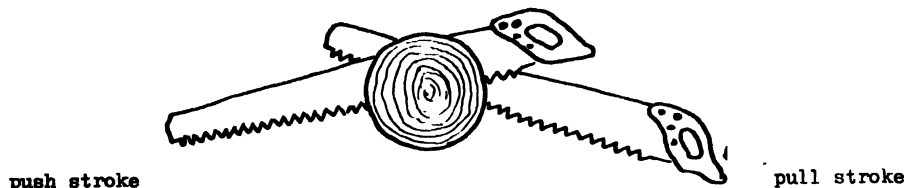
- (v) deburr the tooth rear with a small flat file or grind-stone;
- (vi) lower and file rakers by means of dressing tool. The interior angle of the raker should be  $90^{\circ}$ .



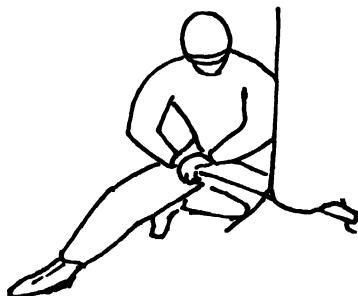
interior angle of the raker

### 3.2 One-man saw

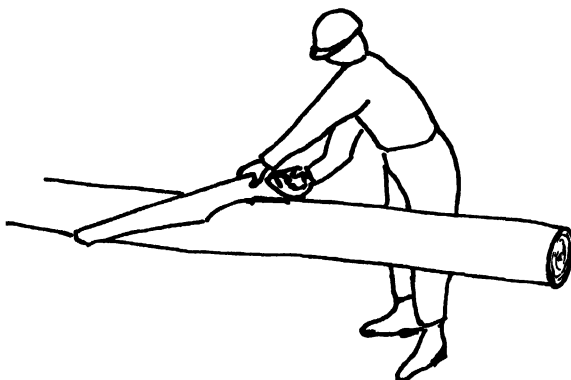
This saw is used to cut wood with diameters of under 30 cm. The length of the saw blade is up to 80 cm. It should have lance teeth. When pushing as well as pulling the cutting teeth have to remain close to the timber. For push strokes the saw front is lead downward, for pull strokes the handle. This gives the most favourable cutting direction to the cutting teeth and increases the cutting performance.



To work the one-man saw, one hand is used to hold the handle while the other presses against the saw back.



body position for a felling cut



body position for cross-cutting

#### **Sharpening the one-man saw:**

The sequence of maintenance items is just as for the two-man cross-cut saw.



## AN INTRODUCTION TO CABLE EQUIPMENT USED FOR WOOD EXTRACTION

by

Rudolf Meyr  
Forstliche Bundesversuchsanstalt<sup>1/</sup>

The equipment used in forestry for cable logging is divided into cableways and cable cranes.

### 1. CABLEWAYS

Mostly semi-stationary, cableways may also be stationary if required. They permit the transport of timber, and to a limited extent also that of other goods, between two fixed points, the loading and the unloading stations. Under certain conditions further intermediate stations may be added, but outside the stations loading and unloading is not possible. Therefore, cableways are particularly suited for logging from inaccessible plateaux, and from terrain where loading along the route is not necessary. The timber to be transported by cableway has to be taken to the loading station by other means.

Some types of cableways may be used as gravity systems (without an engine) provided that the skyline has the minimum gradient required (e.g. types 3.1.1; 3.1.2; 3.1.2.B). Others provide downhill transport by means of gravity but the return trip of the unloaded carriage requires an engine (e.g. type 3.1.2.A). Finally, there are cableway systems that need an engine for all operations. This is also true of any kind of uphill transport, of transport along corridors with insufficient skyline gradient, as well as of transport along counter slopes.

As the opening up of forests advances through road construction, the importance of cableways for logging in intensively managed mountainous areas has considerably declined. Nowadays they are used only in special cases. The relatively high consumption of time and the costs for setting up and dismantling cableways are responsible for their decline in countries with a high wage level and scarce labour force. In areas with a low wage level, a sufficient labour force and forests that provide difficult access to vehicles, technological and economic considerations justify the use of cableways for logging even today.

### 2. CABLE CRANES

Cable cranes are logging devices that thanks to their construction and design can easily be transported, set up and dismantled. They are suitable for uphill and downhill transport of timber, loading and unloading being possible at any desired spot along the route (skyline). In addition, a direct lateral dragging of timber by means of the mainline from areas adjoining the route (in a range of 50 m on both sides) is feasible during an uphill or downhill operation. Thus, a cable crane allows almost continuous removal of timber from the cutting site. Logging with cable cranes causes minimal damage to the soil and stand; therefore, it is also advisable for critical slopes as an alternative to skidding.

Only cable cranes with the required skyline gradient can use gravity (without an engine) in downhill logging. For all other operations, including dragging loads to the carriage, engine power is necessary. Therefore, all cable cranes have to be equipped with a sufficiently strong engine.

<sup>1/</sup> Forestry Research Institute, Vienna

According to their use cable cranes may be divided into two groups:

Short distance cranes are employed for distances of up to 500 m mainly for uphill and downhill logging. The time used for setting up and dismantling is relatively short with a low-mounted skyline, simple supports and by using efficient rigging methods. The time used for setting up accounts for only 15-20 percent of total logging time. Timber transport by short distance cable cranes is mainly tree-length transport under the "raised-head" method, that is, the stems are roped and raised at one end only. The other end trails along the ground. By this means even heavy loads of timber may be carried from the felling site to the road.

Long distance cranes are used in Central Europe for strips between 500 and 1 500 m long, mainly for downhill logging. The timber must be freely suspended for the equipment to operate smoothly, the skyline must be high above the ground. Therefore, setting up is not as simple as in the case of short distance cranes and takes longer. It accounts for between 40 and 50 percent of total logging time.

The maximum load that may be transported is limited by the load capacity of the cable equipment. In Central Europe most frequently cable cranes with a load capacity of 2.5 t are used.

### 3. CLASSIFICATION AND DESCRIPTION OF THE MOST IMPORTANT CABLEWAYS AND CABLE CRANES USED IN FORESTRY

#### 3.1 Cableways

##### 3.1.1 With suspended wires

###### Description:

1 skyline (wire or steel rope)

A variety of hooks for attaching the load (wooden hooks, simple hooks, hooks mounted on pulleys, etc.)

Gravity drive only

Direction of transport: downhill only

Minimum skyline gradient: about 18 percent

Maximum skyline length: about 1 200 m

Performance: depends upon the length of the cable

Application: logging of timber assortments 1 m long, bark, etc., up to a weight of 50 kg

##### 3.1.2 Pendulum cableways

###### A. Mono-track pendulum cableways

###### - With open-end mainline

###### Description:

1 skyline - 1 open-end mainline

1 carriage (fastened to the mainline)

1 yarder (cable winch)

Position of the yarder: on the mountain

Direction of transport: mainly downhill, uphill possible

Minimum skyline gradient: about 20 percent

Maximum skyline length: about 1 500 m in theory, over 1 000 m not advisable

Performance: depends on corridor length

- With endless mainline

Description:

1 skyline - 1 endless mainline  
1 carriage (fastened to the mainline)  
1 yarder (with parabolic pulley)  
Position of the yarder: landing at road side  
Direction of transport: mainly downhill, uphill possible  
Operation: independent of skyline gradient (also possible on flat strips or over counter slopes)  
Maximum skyline length: about 2 500 m in theory, over 1 500 m not advisable  
Performance: depends on corridor length

- Serial cableways (variant of the above)

Description:

1 skyline - 1 endless mainline  
Several carriages (about 5) detachable from the mainline  
1 yarder (with parabolic pulley)  
Performance: depends on the skyline length. Because of more carriages it gives better output than the type with one carriage; skyline lengths of up to about 2 500 m are possible  
All other features similar to the one-carriage type

B. Two-track pendulum cableways

Description:

2 skylines - 1 endless mainline  
2 carriages (fastened to the mainline)  
1 braking station (for gravity drive) or  
1 yarder (for engine operation)

- With engineless gravity drive

Position of braking station: on the mountain  
Direction of transport: downhill  
Minimum skyline gradient: about 20 percent  
Maximum skyline length: about 2 500 in theory, over 1 500 not advisable  
Performance: depends on skyline length

- With engine drive

Position of yarder: on the mountain or in the valley  
Direction of transport: mainly downhill, uphill possible  
Operation: independent of skyline gradient  
(also possible over flat strips or counter slopes)  
Maximum skyline length: about 2 500 m in theory, over 2 000 m not advisable  
Performance: depends on skyline length

### 3.1.3 Round cable

#### Description:

2 skylines - 1 endless mainline  
Numerous detachable carriages (their number depends on skyline length)  
1 braking station (for gravity drive)  
1 yarder (for engine operation)

#### - With engineless gravity drive

Position of the braking station: on the mountain  
Direction of transport: downhill  
Minimum skyline gradient: about 15 percent  
Maximum skyline length: technically not limited, may amount to several km (the longer the corridor the more carriages may be used)

#### - With engine drive

Position of the yarder: on the mountain or in the valley  
Direction of transport: mainly downhill, uphill possible  
Operation: independent of skyline gradient (also possible along flat strips or counter slopes)  
All other features: similar to gravity drive

### 3.1.4 Lasso cable: (special form) (with endless cable similar to chair lifts)

#### Description:

1 endless circulating cable  
A number of pulleys (to lead the cable over the changing terrain gradients of the corridor)  
A number of detachable hooks: specially shaped (for attachment of the load to the cable)  
1 yarder with cable tensioning device  
Position of the yarder: next to the road (landing)  
Operation: up to a slope gradient of about 35 percent  
Cable length: up to 2 000 m  
Loading and unloading: all along the endless cable (cable about 1 - 2 m above the ground)  
Performance: independent of cable length (the longer the cable the more loads can be attached to it)  
Application: logging of timber assortments with a length of 1 m and with a maximum weight of 80 kg with single suspension and of timber assortments with a maximum length of 4 m and a maximum weight of 500 kg (with double suspension)

### 3.2 Cable cranes

#### 3.2.1 Long distance

(In most cases freely suspended loads and skyline high above the ground are necessary)

- With open-ended mainline

Description:

A skyline - 1 open-end mainline  
1 carriage (with or without stopping devices)  
1 yarder (motor driven sledge winch)  
Position of the yarder: on the mountain  
Direction of transport: mainly downhill, uphill possible  
Minimum skyline gradient: about 20 percent  
Maximum skyline length: about 2 000 - 2 500 m in theory, over 1 500 m not advisable  
Performance: independent of corridor length

- With endless mainline

Description:

1 skyline - 1 endless mainline  
(1 lifting cable for various carriage models)  
1 carriage (with or without stopping devices)  
1 cable yarder (with parabolic pulley)  
Position of the yarder: advisable at the landing next to the road  
Direction of transport: both ways possible  
Operation: independent of skyline gradient (also possible along flat strips and over counter slopes)  
Maximum skyline length: about 2 500 m in theory, over 1 500 m not advisable in practice  
Performance: depends on corridor length

3.2.2 Short distance

(with "raised-head" logging and skyline close to the ground)

- With skyline and open-end mainline

Description:

1 skyline - 1 open-end mainline  
1 carriage (mostly with lifting block) - 2 stopping devices  
1 yarder - (motor driven sledge or self-propelled winch, also tractor winch)  
Position of the yarder: on the mountain next to the road (landing)  
Direction of transport: uphill only  
Minimum skyline gradient: about 30 percent  
Maximum skyline length: about 300 m  
Performance: depends on the corridor length

- With skyline, mainline and haulback line

**Description:**

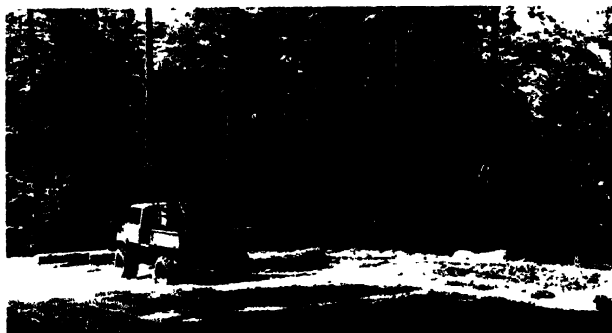
1 skyline - 1 open-end mainline - 1 open-end haulback line  
(1 lifting cable for various carriage models)  
1 carriage (with or without stopping devices)  
1 yarder with 2 winch drums; mostly combined with a tower of  
6-12 m and a skyline tensioning device mounted on a truck or  
Unimog (mobile cable crane unit)  
Position of the yarder: always next to the road (landing)  
Direction of transport: mainly uphill, downhill possible  
Operation: independent of skyline gradient  
Maximum skyline length: about 500 m  
Performance: depends on skyline length

**3.2.3 High lead system**

(short distance cable operation without skyline: mainly "raised-head"  
transport of timber)

**Description:**

1 open-end mainline - 1 open-end haulback line  
(1 lifting cable for various carriage models)  
1 simple carriage  
1 yarder with 2 winch drums (independent unit or mounted on a tractor)  
1 tower for lifting mainline and haulback line mostly mounted on a  
winch or tractor  
Position of the yarder: always next to the road (landing)  
Direction of transport: mainly uphill, downhill possible  
Operation: independent of gradient  
Maximum length: about 250 m  
Performance: depends on cable length  
Footnote: haulback line takes over function of the skyline.



Urus-Unimog mobile cable unit positioned at the road, ready  
to transport logs uphill (Photo: Federal Forestry Research Institute)

## WORKING INSTRUCTIONS FOR CABLE CRANE INSTALLATIONS IN AUSTRIA

by  
Anton Trzesniowski  
Forstliche Ausbildungsstätte Ossiach 1/

### 1. INTRODUCTION

Forestry practice, the existing legal regulations, and above all the practical experience gained from inspecting cable crane installations were taken together and incorporated into a set of working instructions.

### 2. LEGAL REGULATIONS FOR CABLE CRANE INSTALLATIONS IN AUSTRIA

2.1 Federal Law Gazette No. 440/1975 Forestry Law, Part 5: Logging Section 58 to 66.

2.2 Federal Law Gazette No. 43/1977, Section 27: Regulation for the protection of employed persons.

2.3 Federal Law Gazette No. 46/1969, Section 5: Provincial law governing logging roads and cableways, 1969.

2.4 Federal Law Gazette No. 2/1971, 2nd Regulation of the Provincial Government of 1st December 1970, 21, Agriculture - 155/3/1970, concerning safety in using logging installations and the prevention of all dangers involved in logging installations.

2.5 Austrian regulations governing electrical installations

L1/1956 Low voltage lines

L11/1967 High voltage lines

with regard to safe distances from and crossing of power lines, contact the local electric power company (owner of the lines) in order to take the necessary safety precautions.

2.6 Telecommunications: before radio and telephone systems are used, the local telecommunications office must be informed.

2.7 Federal Ministry of Transport (Civil Aviation Authority): according to Federal Law Gazette No. 253/1957 an application (one original and six copies) together with technical descriptions is to be made for installations which are higher than 100 metres above ground level.

2.8 When the height of the cable or the supports exceed 36 metres, the Provincial Government must be notified (Department 19).

2.9 In all other cases in which cable crane installations might interfere with the public interest (mining, roads, military installations), or in case of doubt, information shall be obtained from the local authorities.

### 3. TECHNICAL REQUIREMENTS

For cable crane installations which are subject to formal approval, an application must be sent to the district governor's office together with at least two copies of the following documents:

1/ Forestry Training Centre Ossiach, Austria

3.1 Map showing the corridor of the planned cable crane installation (scale: 1 : 2 880 or similar).

3.2 Longitudinal profile of cable crane installation with the location of supports, sag of cable with and without load, minimum and maximum height of cable above the ground, loading stations, deflection angles of skyline and other important data.

3.3 Technical description of the entire cable crane installation, especially drive unit, braking system - if possible giving specific technical details; include any workshop drawings or leaflets.

Indicate distance from or crossing of railway lines, power lines, telephone lines, public roads or other routes, property belonging to third parties, rivers, torrents, log landings near torrents, etc.

3.4 Certificates for skylines and main lines (provided by the suppliers of wire ropes) stating the diameter of the cable, the number and strength of wires, the breaking strength and the manufacturer's name. Calculation of the load to which the cable will be exposed on the basis of the actual condition of the cable; or calculation of horizontal tangential angle or of the break angle on the basis of cable tension.

3.5 List of all landowners within the area of the cable crane installation together with their land register numbers and, if necessary, a declaration of the landowners' consent to the project.

3.6 Working instructions for the cable crane installation which fully guarantee its safe and accident-free operation and maintenance.

3.7 For cable crane installations of more than 100 metres above ground level, Item 1.5 of the legal regulations will have to be applied.

3.8 When the height of the cable or the supports are more than 36 metres above the ground, it is necessary to inform the Provincial Government of the exact site of the installation (map showing location with the highest points). Maximum tree height along the cable corridor should also be given.

#### 4. FURTHER TECHNICAL REQUIREMENTS

(In accordance with Item 1.2 of the legal requirements).

4.1 The skyline as well as the drive unit must be properly earthed (grounded) (e.g. use an earth spike or attach a galvanized cable for lightning protection at the end of the skyline and bury it in the ground in the direction of the cable - about 30 cm deep and over a distance of 15 - 20 m).

4.2 The manufacturer's nameplate must appear on the cable winch (yarder), showing the following information: type of winch, year of construction, maximum line pull, maximum cable length that can be wound on to the winch drum and cable diameter).

A suitable fire extinguisher must be available.

4.3 At crossings with public roads, warning signs must be put up on both sides at a distance of at least 50 m saying "Attention, Cable Crane". In special cases, gates must also be constructed which are opened only when the cable crane is not in operation.

4.4 If the cable crane installations lead on to areas used by public traffic, where there is the danger of logs which are being transported rolling off, these areas must be adequately



protected by barriers. If possible cable crane installations are not to be set up in the vicinity of public traffic (railway lines, public roads exposed to heavy traffic, etc.).

4.5 All driving or other moving parts of the machine (sprocket, chain and V-belt drives, shafts, air brakes, etc.) must be safely enclosed or adequately guarded against being accidentally touched. When the driving unit is enclosed, air brakes must be arranged outside the drive unit. The platform of the winch and other working places situated more than one metre above ground level must be properly fenced with a railing and a walkway. Safety devices must be maintained in good working order.

4.6 The installation is to be inspected in its entirety by a certified technical inspector. Official records of the results of these inspections are to be kept.

## 5. WORKING INSTRUCTIONS

For the cable crane .....  
cable corridor ..... no.  
operated by .....

5.1 The cable crane shall be used exclusively for the transport of wood and other material. The transport of persons is thus prohibited.

5.2 The forestry official directly responsible for supervising the operation of the cable crane is Mr. .... (district office).

5.3 Mr. .... is responsible for the proper operation of the cable crane. His instructions are to be carried out under all circumstances. Moreover, one person shall be made responsible for each separate working site, such as mountain, intermediate and/or valley stations.

5.4 All persons engaged in the installation and operation of cable cranes must be fully informed of the working instructions before setting up and operating the cable system. They must certify this with their signature and the date. All persons must receive a copy of these working instructions.

5.5 The maximum load per haul is ..... m<sup>3</sup> or kg (payload). (These figures shall under no circumstances be exceeded since a safety factor of 5 must be kept for the mainline.)

5.6 Transport speed must not exceed ..... m/sec or approximately ..... minutes for the transport of one haul. (Air brakes ensure constant travel speed.)

5.7 Cable winches (yarders) must be installed and attached in such a way that they will not change their position or be turned over by the load or other influences. (At a distance of at least 20 times the width of the winch drum a pulley must be securely fixed so as to ensure continuous feeding of the main line on to the drum.) Guiding or touching the moving cables directly with one's hands is prohibited.

5.8 The cable operation shall begin only after all of the various stations have been informed and a reliable means of communication between them has been established (visual signalling is permissible only for small, clearly arranged installations - not exceeding a total length of some 100 m. In all other cases a telephone or radio system is necessary.)

5.9 Signalling shall be done as follows:

STOP LINE = one long sound (or light signal)  
SLACKEN LINE = two short sounds (or light signal)  
PULL LINE = three short sounds (or light signal)

EXAMPLE OF VISUAL SIGNALLING

A	B		
<u>PULL CABLE</u>	<u>SLACKEN CABLE</u>	<u>STOP</u>	<u>SWITCH OFF ENGINE, VERBAL</u>
	wave lowered arm in the	wave raised hand	<u>COMMUNICATION NECESSARY</u>
	direction of the cable	over one's head	arms crossed above one's
			head.

EXAMPLE OF SIGNALLING (SOUND OR LIGHT SIGNALS)

1. one signal - STOP
2. two signals - SLACKEN CABLE
3. three signals - PULL CABLE

Any signal that is not understood means "STOP".



One tree intermediate support used in a cable crane operation (Photo: E. Pestal)

## WORKING INSTRUCTIONS FOR OPERATING WHEELED TRACTORS AND GROUND CABLE WINCHES

by

Anton Trzesniowski  
Forstliche Ausbildungsstätte Ossiach 1/

### 1. INTRODUCTION

These instructions for operating forest machinery were drawn up in order to obviate additional dangers through more expert knowledge. By skidding vehicles we mean wheeled skidders and agricultural tractors with attachments for forestry work.

### 2. GENERAL

Before beginning the operation and whenever necessary, the employer and the workers shall decide what method of felling and logging is the safest for the particular conditions of the site.

The machines, tools and devices to be used must be supplied in good working conditions.

The supervisor (district forester) is responsible for the general supervision of the operation. In addition to him, one worker is to be appointed to supervise each separate working site (felling, logging, bucking).

All workers engaged in the operation are required to affirm with their signatures that they have received the working instructions from the head office of the forest enterprise. Furthermore, one official (supervisor, forester) is responsible for giving additional working instructions whenever necessary.

### 3. GENERAL REGULATIONS FOR FELLING AND SKIDDING

When trees are being felled within the felling area (radius: 1.5 times the tree length), both delimbing and skidding are prohibited. Felling is likewise prohibited during delimbing and skidding within the felling area.

During uphill or downhill skidding, felling, delimbing, and bucking are not allowed within the fall line of this area.

As a matter of principle felling is carried out by one worker (a one-man operation) and no other person is allowed within the working range of the power saw when operated. If, as in special cases, a second worker is required for wedging, the power saw should be switched off during this work.

In the case of a storm, icy surfaces or thick fog, felling and skidding must be stopped.

### 4. REGULATIONS FOR LOGGING

a) Site of operation. The site of operation shall be marked off with the warning and no-entry signs required by forest law.

All piles of logs shall be arranged and supported in such a way so as not to collapse or allow the logs to slide or roll off.

Mr. (the authorized operator's name) shall be responsible for the proper operation and maintenance of the machine. The operator is required to wear a suitable safety helmet and ear plugs or muffs. Work gloves and sturdy work shoes are highly recommended.

Before beginning work, all persons engaged in operating the machines (including all types of work, such as felling, skidding and bucking) must be informed of the contents of the working instructions. In case of an emergency it is particularly important that all persons engaged in the operation be able to start and stop the machine. They are required to certify with their signature that they have fully understood the working instructions.

b) Maintenance of the machine. During cleaning and maintenance work on the machine, particular care shall be taken to prevent the machine from being started accidentally or by unauthorized persons. Servicing the machine must be carried out only when the engine is switched off. Lubrication and maintenance shall be carried out on all parts of the machine according to the manufacturer's instructions. Care shall be taken to make sure there is sufficient lubricant, that the proper tools are operational for servicing the machine, and that any spare parts that might be necessary are available. Under no circumstances shall tools be left lying on the machine; they must be kept locked up or attached to the machine. A fire extinguisher shall be available at all times.

c) Main line (traction cable) and chokers. The main line and the chokers shall be inspected periodically for defects, kinks, broken wires, excessive wear and to ensure that they are properly attached to the chokers. Damage is to be repaired immediately. Defective ropes must never be used. The main line and chokers shall not be dragged empty behind the skidder when driving.

d) Anti-skid chains. As a matter of principle the anti-skid chains must be properly mounted and tensioned on all the wheels according to the regulations. Chains shall be used in all cases except in particularly favourable conditions.

e) First-aid materials. Sufficient first-aid material and a first-aid booklet shall always be on hand and the dressings shall be kept sterile.

f) Maximum load. The maximum permissible load depends on the local conditions, e.g. terrain, weather conditions, ground surface conditions, the strength of the main line (traction cable), winch capacity, type of attachments, etc.

When the load is attached, the slings must fit tightly. The load must not become detached by itself under any circumstances. In downhill extraction the heaviest log shall be attached to the first choker.

g) Winching of a load. Winching of a load towards the skidder shall begin only after a clear exchange of signals has been carried out. All visual or acoustic signals must be agreed upon before the operation begins.

Before being driven off, the load shall be winched up close to the skidder so that the front ends of the logs are lifted off the ground ("raised head" method).

When the load is winched laterally, excessive angles must be avoided and the rear axle of the skidder shall be perpendicular to the direction of the cable. The skidding blade is to be used as an additional aid. No one is allowed within the interior angle (the bight of the line) of the loaded cable.

The driver must not leave the skidder while winching is in progress. Any remote control device must be equipped with an emergency switch.

Guiding or touching moving cables with one's hands is prohibited.

While winching the load downhill, the skidder must be at an angle to the fall line. The drum-end of the main line (traction cable) must come off the drum easily.

n) Operating the skidder. The skidder shall be started only after auxiliary personnel have left the danger zone. The workers must keep a safe distance from the moving main line and from the danger zone of the attached load (hazards include swinging, whipping and rolling of logs, among others). No worker shall stand in the bight of the line.

The skidder must be set slowly and gently into motion (to avoid ruptures of the cable or of the chokers).

During off-road driving the appropriate gear must always be selected, especially when going downhill. The braking effect of the blade must be considered. Moderate speed is to be maintained and excessive braking avoided. When the wheeled tractor is being driven over uneven terrain, the trailer or the load may become detached.

Great care should be taken - if necessary, release cable (winch) brake.

When backing up the operator must look behind him.

After completing the work the skidding blade must be lowered to the ground, the machine put into the lowest gear, the brakes applied and adequate precautions taken to avoid the engine being started by unauthorized persons.

The master switch must be turned off.

#### 5. SPECIAL INSTRUCTIONS FOR INDEPENDENT GROUND AND TRACTOR CABLE WINCHES

The winch operator shall not stand on the side where the cable is fed on to the winch.

Snatch blocks must be securely fixed.

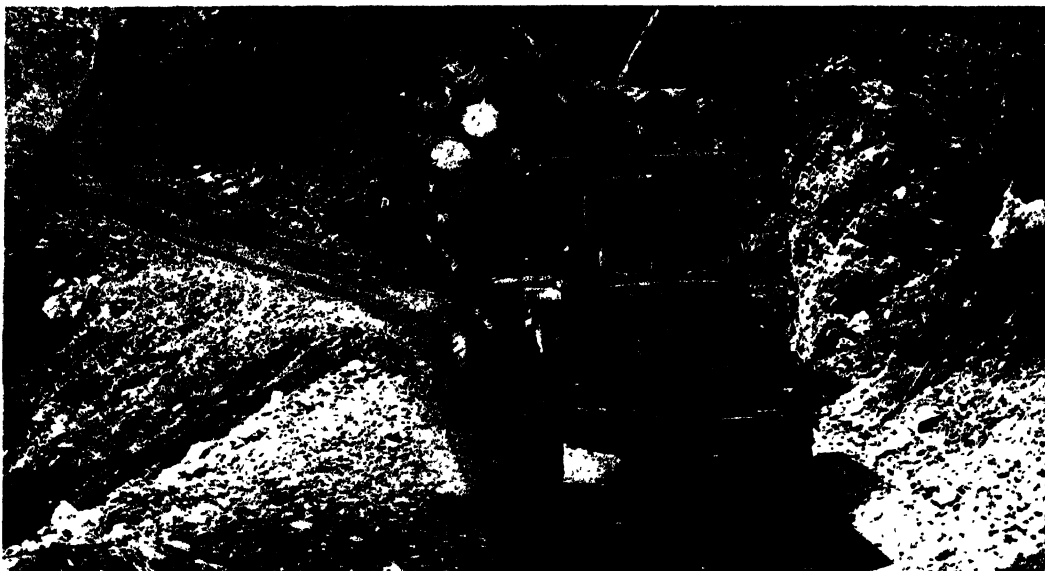
Prior to work beneath power lines, it is necessary to obtain the authorization of the local electric power company and to carry out whatever safety measures are required.

Prior to work with cable winches mounted on a tractor, measures must be taken to prevent the tractor from slipping or rearing up.

#### 6. SPECIAL INSTRUCTIONS FOR ARTICULATED WHEELED SKIDDERS AND WHEELED TRACTORS

It is important to make sure that the safety grids and the cabin itself are sufficiently strong.

Particular care shall be taken when turning the vehicle on slopes since there is a danger of its overturning. Using the traction cable as an anchor and lowering the blade can be extremely helpful.



Forwarders have been used successfully in areas with wind-damaged timber and for the transport of small quantities of timber in farm forests (Photo: E. Pestal)



The MB-Trac fills the gap between a farm tractor and a skidder. Its cable equipment and a comfortable two-man cabin make it increasingly popular (Photo: E. Pestal)

## REQUIREMENTS FOR WHEELED TRACTORS USED IN FOREST WORK

by  
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With a view to lightening hard manual work, particularly in wood harvesting, forest engineering seeks to use machinery and vehicles in all forest operations wherever possible. The performance and efficiency of operators and machines depend essentially on both the training level of the personnel and on the degree of mechanization of the forest enterprise.

The larger the forest enterprise, the easier it will be to mechanize forest operations. It is imperative in any case to select the right type of machines and to provide these with all auxiliary equipment needed to meet the specific requirements of each individual enterprise.

About 60 percent of all skidding operations in Austria are carried out by wheeled tractors which have genuine or false four-wheel drive. (False four-wheel drive means that the front wheels are smaller than the rear ones.) Twenty percent of these tractors have a genuine four-wheel drive and Ackermann steering, and 20 percent are articulated wheeled skidders.

### A. SAFETY REQUIREMENTS FOR FOREST TRACTORS USED IN MOUNTAINOUS TERRAIN

Most forest tractors, including articulated four-wheeled skidders and tractors with genuine four-wheel drive and Ackermann steering, are designed to be used in flat to hilly terrain. Therefore, additional equipment, or at least a reinforcement of individual vehicle components, is a necessary safety precaution if the tractor is to be used in mountainous terrain.

#### 1. The driver's cab

Although some types of tractors are not equipped with a genuine cab, the safety features described below are required to protect the driver:

- a) There should be a protection grid behind the driver's seat. This should consist of iron rods, at least 15-20 mm thick and extend forward on both sides to protect the driver but, at the same time, permit easy access to the driver's seat.
- b) The roof of the driver's cab must be sufficiently sturdy or be reinforced so as to provide him with adequate protection against its perforation if the vehicle overturns.
- c) The cab should be properly padded with sound deadening material, foam rubber; the exhaust pipe system should provide adequate protection against noise and be equipped with a spark arrester. The noise level inside the cab should not exceed 85 decibels (standard for Austria).
- d) The driver's seat should be ergonomically designed so as to prevent the driver from sliding around while sitting in it. The seat should be body-contoured with a high backrest. In addition, lateral armrests, which can be tilted upward, should also be foreseen, if possible. Handles must be provided on both sides of the driver's seat, so that the driver can hold on to these in case the tractor overturns.

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Up to now, the opinion is still divided on the usefulness of safety belts. As long as these are not offered as standard equipment, no practical experience can be gained.

e) A windscreen with wipers has proved to be of advantage, particularly in winter. Adequate ventilation and cooling are just as important in summer as proper heating is in winter.

f) A loud horn and ignition lock which can be switched off, as well as a master switch, must be provided.

g) Inside the cab, all elements (battery, tool-kit, first-aid kit, fire extinguisher, spare parts) must be securely attached so as to remain in place in case the vehicle rolls over.

The first-aid kit may be fixed on the rear panel inside the cab, whereas the required tools should be mounted on the outside.

## **2. Driving - steering - braking**

a) The hydraulic steering system should be independent of the other hydraulic units and permit uniform steering at different driving speeds. A steering wheel is preferable for extensive travel by road, whereas lever steering is better for cross-country driving.

b) The articulated steering system should comprise two hydraulic cylinders so as to remain operational in any situation.

c) A power-shift would result in heightened manoeuvrability and greater safety of the tractor.

d) A dual-circuit brake system would also be of great advantage and a disc brake would result in a better braking effect.

e) Experienced tractor drivers often insist that differential locks be provided on the front and rear wheels, as these add to the safety of the tractor.

f) A properly functioning handbrake is indispensable not only in road traffic, but also for one-man jobs.

## **3. Cable winch - main line - rear plate**

a) In order to cope with emergency situations, it should be possible to release or dislodge hydraulic cable winches mechanically in the event that the engine should come to a sudden standstill.

b) The end of the main line must be fastened on the cable drum in such a way that it unreels easily in emergencies.

c) The lower edge of the rear plate should be sufficiently sturdy in the middle so as to protect efficiently the rear axle and the differential gear casing against logs hitting it. The plate should extend over two-thirds of the width of the rear wheels. These "mudguards" must be reinforced by lateral ribs on the wheel side and must project forward on the outside so as to form a cup-shaped concave opening to guide the attached logs.



The upper edge of the "mudguards" and of the remainder of the plate must be fitted with a sturdy deflector grid of sufficient height to keep the attached logs from sliding forward.

d) Rear plates which can be hydraulically lowered and have a serrated lower edge are best suited to mountainous terrain because they can prevent the attached logs from sliding forward under the vehicle - a much feared situation. Moreover, in cases of emergency braking the lowered rear plate provides a better additional braking effect than the front blade does.

#### 4. Wheels and non-skid chains

a) Wheel (tyre) valves must be protected by welding on sufficiently strong iron covers. The tyre profile should be such as to throw off snow and earth material.

b) To improve their grip, the tyres should be filled with water (in winter, antifreeze must, of course, be added). When the axle pressure is not uniform (top-heavy), it is advisable to fill the tyres on the axle bearing the smaller load (mostly this is the rear axle) with water.

c) Non-skid chains must be properly mounted (not too loose-fitting, not too tight); and they must not hang against the articulated four-wheeled skidder.

#### 5. Equipment for trips on public roads

For drives on public roads the tractor must be fitted with two front and two rear direction-indicator lights, which must be easy to mount, two headlights at the front and two stop-lights as well as two tail-lights at the rear. The licence plate must be fixed at the height stipulated by law and be provided with reflectors and lighting. Tractors must be equipped with a horn and a hand-brake. Emergency lights are a useful addition.

#### 6. Optional equipment

a) An engine-driven small cable winch (3.5 - 5 hp, with about 100 m of 8-mm cable) is useful for pulling the main line uphill - if done manually, this is a most cumbersome operation - where timber is transported downhill in terrain not accessible by tractor.

b) A complete grapple unit with guide pulley and auxiliary cable should be available on every tractor as this is needed for putting a vehicle back on its wheels after it has rolled over.

#### 7. Special equipment for the driver

The usual helmet for forest workers with chin straps and complete with ear-plugs or mufflers is the best protective helmet. Working gloves are an absolute must for the driver. His shoes must in all cases have skid-proof soles. Suitable working clothes should be available for all weather conditions. Moreover, working clothes should prevent operators from getting caught by obstacles.

## B. SAFETY REQUIREMENTS FOR AGRICULTURAL TRACTORS USED IN FOREST WORK

Proper training of the tractor driver and an engine suitable for forest work are pre-requisites for using an agricultural tractor in forest operations.

As regards the driver, it should be pointed out that special training and adequate working clothes are decisive factors for safety and efficiency. A good protective helmet, working clothes and sturdy shoes with skid-proof soles are necessary. As regards the tractor, this should be as follows:

- a) It must be equipped with a protective top. This is an absolute necessity in forest work and required by law in many countries. A driver's cab with a heating and ventilation system especially designed for forest work and noise proofing to a maximum of 85 decibels would be desirable.
- b) Branch deflectors with front protection are not common features of agricultural tractors; however, these are necessary to protect the exhaust pipe (which should be run below the protective top) and the windshield, and to reinforce the protective top.
- c) Tyres must have a very good profile to throw off snow and earth material easily and ensure optimum grip.
- d) For slope work and in winter operations, non-skid chains must be mounted on all four wheels. Care should be taken to mount the chains in such a way that these are neither too loose nor too tight and that the material which gets stuck in the tyre treads is immediately thrown off.
- e) Ballast weights and tyres should be filled with water to increase the grip of the vehicle.
- f) The valves of all wheels (tyres) should be protected to avoid unnecessary repairs.
- g) The brakes should always be in perfect working conditions and must act uniformly on all four wheels.
- h) Protective screens should be provided on all signal and indicator lamps and tail-lights to avoid frequent repair costs.
- i) There should be a shield to protect the axles, the engine, the oil sump, brake lines and filters from below. The engine block should also be laterally protected.
- j) Power-assisted steering with a crank button on the steering wheel is highly recommended for cross-country and forest drives.
- k) It should be equipped with a hydraulic system to permit easy mounting of attachments (cable winches, bogies, trailers, grader blades, reforestation machinery).

It is imperative that the driver checks the functioning of all elements on the tractor at regular intervals and that he always carries out the necessary maintenance work immediately.

## MECHANIZED WOOD HARVESTING AND THE OPTIMAL OPENING UP OF FORESTS

by

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### 1. INTRODUCTION

Rational employment of technology will depend on the way in which a forest enterprise is managed. It is therefore necessary to discuss the two operational systems most commonly used by the Federal Forestry Enterprise in Austria, the owner system and the contractor system.

In the owner system the owner - either the state or a private individual - manages the forest himself. He employs managers and forest workers to carry out wood harvesting, forest production and road construction within the enterprise. Twenty years of sometimes painful experience have shown that the following organizational system is most efficient: forest enterprises managed in the owner system are divided into a territorial operation unit and a functional one. The territorial unit is called forest administration (Forstverwaltung). It is in charge of all work to be carried out locally and without any special technological equipment. The administrative personnel plan all management work concerning finances and work technology and carry out the following operations: stand planting, tending, thinning, harvesting of individual trees from snowbreak, windfall or pest control measures, and simple harvesting, i.e. felling and logging by hand or agricultural skidder. Workers can be recruited locally and need no special training. Maintenance and repair work are so simple that they can be done by local car or machine service-shops.

For more complicated technology the administrations depend on assistance from the functional units, which are the Construction and Machine Centres in the case of the Austrian Federal Forest Enterprise, or private contractors. Some very specialised work would exceed the capacity of a forest administration and in addition the Centre's machinery can only be worked to capacity if 10 to 20 forest administrations are supplied. The Construction and Machine Centre is responsible for highly specialised work, calling for expert technical as well as planning skills and know-how.

The Centres have the task of planning and building road-nets, bridges, and other opening-up facilities; the Centre's machinery, which is partly designed and constructed in its own workshops, is employed for highly-mechanized timber harvesting within the forest administrations. The managing and working staff of these Centres must be specially trained and there are central workshops and installations for the repair and maintenance of forest machines. Moreover, the Centres have their own administrative staff and use their own radio system to organize and control the employment of machinery. The Construction and Machine Centres are paid by the forest administrations as if they were private contractors.

Unlike the owner system some forest enterprises are not big enough to install such functional units. They have to call in private firms for highly-specialised and large-scale operations. If a forest enterprise is big enough to run its own Machine Centre, we believe it will work more economically than contractors because specialisation and working to capacity can be better planned and organized. Thus we believe that the operational system described above is for us the most suitable one.

1/ Construction and Machine Centre, Steinkogl, Federal Forestry Enterprise

Within this system, costs can be optimized if the opening-up of forests and wood harvesting are most favourably related. This is basically a planning problem since the most favourable expense ratio between road construction and timber harvesting is calculated on the basis of empirical data. These necessary data include the various timber harvesting methods and their costs, the costs of road construction and road maintenance. In the following points these aspects will be discussed in detail and with regard to the use of advanced technology.

## 2. TIMBER HARVESTING

The timber harvesting method depends on terrain conditions. Costs will depend on whether machines can enter the forest or whether timber has to be transported by cable to the machines positioned on the forest road.

### 2.1 Timber harvesting by skidders

The criteria of a terrain accessible by four-wheel driven skidders include gradient, adverse gradient and soil conditions. On hard soil, downhill transport is feasible at a gradient of up to about 50-60 percent, adverse gradients should not exceed 20 percent. In terms of the kind of soil, muddy terrain is hardly accessible at all to wheeled skidders. Timber is transported according to the whole-tree or full-length methods, which means that felling is carried out manually by means of power saws. In the full-length method, the trees are delimbed by hand at the felling site and subsequently transported to the landing in full length for further cross-cutting. In the whole-tree method, the whole tree is transported to the landing with its branches on and converted at the landing by a so-called "processor". It is a special feature of wheeled skidder transport, that the costs for the transport from the forest to the landing do not depend on a certain or minimum amount of timber available for harvesting in a given area (see also chapter 2.2 - Cable transport); individual very valuable trees or trees broken by wind or snow can be transported to the road at the same costs. Skidder operation is divided into load attachment, loaded travel and load detachment. Only loaded travel and its distance is cost-sensitive, only expenses for loaded travel will influence the road-net density as will be shown later in the paper.

### 2.2 Cable transport

Generally, cable logging is used in terrain steeper than 50%. Cable transport may be uphill or downhill even in almost flat terrain. The type of cable device will depend on the transport distances between felling site and road accessible by lorry. For distances of more than 600 linear m the assortment method is the most economical one. According to this method, the trees are felled, delimbed and cross-cut by power saw. The logs are then transported by means of a skyline system; the load is suspended and can move very quickly. The simplest power unit of a skyline system is a single drum winch mounted on a sledge. The winch is driven to the highest point of felling since the cable system works by gravity. Installing this kind of cable device is very cheap since the haul-back line is superfluous. For transport distances of below 600 linear m the whole-tree or full-length methods are most economical. It is obvious that the tree will be trailed with one end along the ground since the supports are made of trees and cannot exceed tree height. "Raised-head" transport is, of course, slower but within the distance mentioned the attached quantity (one whole tree instead of 5 to 6 logs) and a higher carrying capacity make up for this shortcoming.

Full length or whole trees can be transported uphill or downhill by means of cable devices with an inclinable tower. Here we distinguish between operations for which supports must be built and those for which tensioning alone is sufficient. Lowering and lifting of the load during transport is carried out in the first case by a specially designed carriage or, in the second case, by tensioning and slacking of the skyline (live skyline). Different from skidder transport, costs of cable transport will depend on the quantity of the timber produced since costs for mounting and dismantling the cable installation have to be added

to mere transport costs. It is, of course, a decisive factor whether these fixed costs are borne by 100 or 1 000 m<sup>3</sup> of the timber produced. It has not proved economical to harvest amounts of below 100 to 150 m<sup>3</sup>. Individual trees felled by wind or snow cannot be logged efficiently by cable. Since the timber quantity from snowbreak or windfall accounts for 10 to 15 percent of all timber produced, this share will have to be disregarded for profit calculations of timber production unless conditions are extremely favourable for helicopter logging.

So far, we have been discussing final cuts, which means that definite areas are clear-cut. Transport of timber from thinnings, i.e. selective felling of individual trees from a remaining stand, is more problematic. No matter whether skidder or cable devices are used, the remaining stand will be damaged and damage increases the greater the distance from either the felling site to the landing as well as to the road or to the cable line. Transport distances are almost always limited to not more than 300 m.

### 3. ROAD CONSTRUCTION

For a mechanized forest enterprise roads must be accessible by lorry in any weather. Construction costs vary considerably since they depend on terrain conditions, the geological formation, the gradient, the amount of additional roadwork for drainage and the distance from the supply of subgrade material. Thanks to modern blasting methods road construction is presently cheaper in rocky terrain than in muddy or soft terrain. The costs charged on each m<sup>3</sup> of timber produced by road construction end with the writing-off period, which can be in a range from a few to 20 years, depending on the profitability of the operation.

#### 3.1 Road maintenance

Costs for keeping roads accessible all year - including snow removal in winter - are not as variable as costs for road construction and they can thus be calculated more easily. They depend on the quality of water discharge devices and on the distance from the maintenance material supply. Cheap road construction often leads to high maintenance costs. Saving in subgrade and discharge constructions means saving at the wrong end. Costs for road maintenance are always added on to every m<sup>3</sup> of timber produced. They are zero when construction works are concluded and rise for 10 years after which they remain constant. They are as high as or somewhat higher than construction costs per each m<sup>3</sup> of timber produced.

#### 3.2 Cost calculation

Every m<sup>3</sup> of timber produced is charged with the following costs:

- 1) felling costs (power saw and worker or felling machine)
- 2) conversion costs (power saw and worker or processor)
- 3) transport costs from felling site to road (wheeled skidder or cable device)
- 4) road construction costs until the write-off period is over
- 5) road maintenance costs
- 6) costs for general administration
- 7) costs of forest production.

Note: Costs for road construction and road maintenance are only calculated at 80 percent of their actual sums, the remaining 20 percent are made up by non-calculable advantages

for the whole enterprise, such as easier supervision of the area, cheaper transport for hunting purposes, forest production and building maintenance, cheaper transport of workers, machinery, and the like. All costs charged on to each  $m^3$  of timber produced are fixed costs except for transport costs, which vary with the distance from felling site to landing, and construction and maintenance costs, which vary with the road-net density. The variable costs are decisive for planning the road-net density (linear m per ha). For the purposes of better clarity, tables 1 and 2 are included, whose calculations are based on the following assumption

- road construction costs: A.S. 300 per linear m
- amortization of construction costs: after 20 years
- road maintenance costs per linear m and year: A.S. 15
- skidder transport costs per  $m^3$  of timber and linear m of distance: A.S. 0.14.

The conclusions drawn from Table 1 show that for the average data quoted, the optimum road-net density lies between 20 and 25 linear m of road per ha. Such calculations are only of general value. Every special project has to be exactly calculated, since terrain and building conditions strongly influence construction costs and can lead to completely different results. The most important general rule is that changes in the road-net density of areas accessible by skidder influence total costs much less than has so far been assumed. A general example for calculations of cable transport is included in Table 2.

Transport costs in cable logging vary depending on the distance, as do additional costs for mounting and dismantling. Table 2 is based on a timber quantity of 400  $m^3$  per operation. Note that costs for cable operation depend largely on the amount of timber produced in each operation.

Table 2 shows that - as paradoxical as it may seem - increasing road-net density increases harvesting costs slightly if the write-off period is not completed. Only after amortization of the road can total costs be slightly lowered by a higher road-net density. In conclusion, I would like to point out that the figures are there in black and white even though the results sometimes differ from general assumption concerning road-net density. It is most surprising that costs vary only slightly if road-net density is lower. Both tables disregarded equal costs for felling and conversion. If these had been included, variations in percent would have been even smaller. For an expanding forest enterprise that can only invest moderately, it would be more advisable to expand the road-net slowly and above all to concentrate first of all on accelerating mechanized timber transport and conversion. Of course, a relatively dense road-net of, for example, between 20 and 25 linear metres per ha, makes forestry activities easier in many respects, yet the financial advantages are relatively negligible.

Table 1

COSTS FOR SKIDDER EXTRACTION

Austrian Schilling <sup>1/</sup>

Road-net density in linear m per ha (truck road)	10 linear m	20 linear m	30 linear m	40 linear m
resulting transport distance for downhill transport (uphill transport only for the last 50 m)	950 m	450 m	250 m	200 m
construction costs per ha	3,000.00	6,000.00	9,000.00	12,000.00
construction costs per year (20 years of amortisation)	150.00	300.00	450.00	600.00
construction costs per m <sup>3</sup> (increment 5 m <sup>3</sup> per ha/year)	30.00	60.00	90.00	120.00
maintenance costs per ha	150.00	300.00	450.00	600.00
maintenance costs per m <sup>3</sup>	30.00	60.00	90.00	120.00
transport costs per m <sup>3</sup>	133.00	63.00	35.00	28.00
sum total of construction costs, transport costs and maintenance costs per m <sup>3</sup>	193.00	183.00	215.00	268.00
sum total of transport costs and maintenance costs per m <sup>3</sup> after amortisation of the road	163.00	123.00	125.00	148.00

<sup>1/</sup> 1 US\$ = 16.5 Austrian Schilling

Table 2

Road-net density in linear m per ha (truck road)	COSTS OF CABLE EXTRACTION				
	Austrian Schilling <sup>1/</sup>				
	10 linear m	15 linear m	20 linear m	25 linear m	30 linear m
resulting transport distance (one downhill and one uphill operation)	500 m	330 m	250 m	200 m	160 m
construction costs per m <sup>3</sup> (increment 5 m <sup>3</sup> per ha)	30.00	45.00	60.00	75.00	90.00
road maintenance costs per m <sup>3</sup>	30.00	45.00	60.00	75.00	90.00
cable transport costs per m <sup>3</sup>	93.40	86.20	79.00	71.80	64.60
costs for mounting the cable installation	54.80	45.60	36.40	27.20	18.00
sum total of construction costs, maintenance costs, cable trans- port costs and cable mounting costs	208.20	221.80	235.40	249.00	262.80
sum total of maintenance costs, cable transport costs, cable mounting costs after amortisation of the road	178.20	176.80	175.40	174.00	172.60

<sup>1/</sup> 1 US\$ = 16.5 Austrian Schilling



SELECTION OF TREES IN THINNING OPERATIONS  
REMOVAL OF INDIVIDUAL TREES IN SECONDARY FORESTS

by

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1. INTRODUCTION

As early as the 16th century the idea of "tending" became a vital part of forest management. Even then it was recognized that dense stands have to be thinned in order to allow the forests to grow properly. Over the years a variety of thinning methods have been developed. From first thinning, in which only dead and oppressed trees are removed, to extremely high thinning, in which intense intervention is carried out, particularly in the crown section, silviculturists have employed a number of methods in this area of forest management.

Thinning rules such as "early - moderate - often", and expressions such as light - moderate - intense - high or first thinning, are still common in silviculture today. The terms refer to the intensity of the thinning intervention.

Thinning standards are imperative; yet schematic procedures are usually far too general to meet the requirements of individual trees and entire stands at specific phases of their life, and are thus insufficient for carrying out tending with the best results.

The uniqueness of the stand in terms of its individual location and make-up can only be respected by means of dynamic thinning, whose aim is to achieve maximum volume and value increment. The silviculturist has to understand the language of the trees and to sense where problems lie. A good silviculturist in effect talks to his trees. He asks:

Who are you?  
Where are you from?  
Where do you want to go?  
Where would I like you to be?

Such questions can lead to valuable insights in the tending of stands. The intensity of the intervention by thinning will depend above all on the ratio between the height of the tree and the diameter at breast height of the tree - the so-called H:D ratio. Expressed in other terms this ratio represents the amount of green crown in relation to the entire length of the tree.

When selecting trees for thinning, the silviculturist must assess the stability of the stand and carry out a thinning operation that is dynamic, i.e., he must adapt his selection in the way that is best for that particular location and stand.

2. AIM OF THINNING

Thinning reduces the number of individual trees in a stand to a smaller group of stronger trees of higher quality. Thinning serves both to select trees and to assess their growing space and the mixture of species or varieties. Thinning is both tending and harvesting. Dynamic thinning carried out at up to half the rotation age (approximately 50 years) provides, within a considerably short time, stronger assortments, more logs and higher yields and - because of the unit-volume law - lower harvest costs. Whereas the production yield is only negligibly affected, the value increment may be caused significantly as a result of

the greater dimensions and better quality of the wood. Thinning as a means of tending always promotes the root and crown formation of each individual tree, thus raising the production yield of the stand.

One of the most essential aims of thinning, however, is to improve the stability of the stand. The amount of timber damaged by wind or snow is far too great; in the forests of Carinthia in 1979 there were 1 000 000 m<sup>3</sup> of damaged timber, which was 60 percent of the total amount of timber harvested. Dynamic thinning promotes the uniform growth of the stem, crown and roots. This leads to a tall, green symmetrical crown, a low H:D ratio and consequently high stability of individual trees and of entire stands. The trees should attain their target age. In order to thin dynamically, the silviculturist must assess the amount of damage the trees may have to withstand from wind and snow. He must analyze the snowfall records of the past 50 years.

Helping the trees in their constant struggle for light, space, water and nutrients, as well as improving the water and heat balance in the forest soil, leads to an intensification of the life of the soil, a favourable humus composition and thus to a better circulation of nutrients which in turn has a positive influence on the growth of the tree. As with every tending measure, thinning has to be adapted to the particular aim of tending in each case. Before every intervention the following questions must be answered:

- What is there? (survey of actual conditions)
- What should be the result? (target conditions)

A comparison of the actual and target conditions will indicate the proper silvicultural treatment needed for the particular stand.

### 3. THINNING TILL THE AGE OF 50 (HALF ROTATION AGE) EXTENSIVE CUTTING IN THE CROWN SECTION

#### 3.1 Selective thinning

The principle of selective thinning involves the selection, marking and specific measures to promote the growth of elite trees.

##### 3.1.1 Time of first selective thinning

Selection of elite trees should take place only after the final desired distribution of trees has been established. In coniferous and mixed hardwood and coniferous stands, which are not overly dense, it should usually start when the dry-branch zone of the conifers is about 3 - 5 m above the ground. If there is sufficient space or if the young stands have already been tended properly, selection can begin when the dominant height of the elite trees is around 12 to 15 m.

##### 3.1.2 Selection of the elite trees

Selection of elite trees must be determined by the following criteria, listed in order of priority:

- vitality (resistance = low H:D ratio, good crown formation, healthy)
- quality (with regard to stem form, stem damage)
- distribution

Vital (thriving) trees usually have good crowns and are physically resistant. A good indication of the vitality of a tree is its H:D ratio.

The H:D value is easy to calculate. It is derived from the height of the tree (H) divided by its diameter at breast height (D).

e.g. tree height	=	20 m	20 m	20 m
D.b.h.	=	0.25 m	0.20 m	0.15 m
H:D ratio A	20 : 0.25	=	80	
B	20 : 0.20	=	100	
C	20 : 0.15	=	133	

The H:D ratio is of particular importance with regard to the stability and operational safety of tree stands. Trees with an H:D ratio of over 80 can easily be broken by snow and wind. Trees with an H:D ratio of around or below 80 are hardly affected by weather.

Elite trees must have a high chance of survival and the lower their H:D ratio, the higher their chance of survival. When selecting future elite trees, the silviculturist has to consider both the stability of the stand and the fullness of the boles (for better wood quality).

Elite trees have to be of high quality; the higher their quality, the more profitable the yield. In poor-quality stands the quality of the elite trees will also inevitably be lower than in high-quality stands.

#### c) Distribution

Of all the criteria for selecting elite trees, distribution is the least important. However, the space required for each tree in the final stand must be taken into consideration when selecting elite trees.

The following chart is meant to serve as a point of reference:

Tree variety	Approximate space needed at age 100	corresponds to an average dis- tance between trees of:	Approximate number of elite trees per ha
Spruce, fir	25 m <sup>2</sup>	5 m	400
Larch, pine	40 m <sup>2</sup>	6-7 m	250
Douglas fir	35 m <sup>2</sup>	5 m	280
Beech (heavy timber)	60-70 m <sup>2</sup>	8 m	150
Beech (admixture)	30 m <sup>2</sup>	5-6 m	330
Oak	100 m <sup>2</sup>	10 m	100

In mixed stands these distances should be adjusted accordingly. Distribution need not be uniform. If particularly suited elite-tree candidates are grouped more closely together (say, in groups of three or perhaps even four), the distance between the chosen trees can be smaller. In this case, however, a large enough space for the groups should be ensured and the distance from the neighbouring elite trees should be correspondingly larger.

The distances between elite trees can, of course, be larger as well; where there is no elite tree, none can be chosen! Yet if the normal distances are continuously reduced, too many elite trees will be chosen for the area and the space liberated by the removal of competitors will still be too small. In this case not every elite tree can be liberated sufficiently without causing gaps. This results in competition between the elite trees before they reach rotation age.

### 3.1.3 Liberation of elite trees

Elite trees are liberated by the removal of their strongest competitors. Competitors are those trees which restrict the crown section of the elite tree. Thus the removed material consists of dominant and co-dominant trees. Accordingly, the diameter of the removed trees will usually be smaller than those of the elite trees on the one hand, and above the D.b.h. average of the stand on the other. The more vital the elite tree (low H:D ratio) or the lower the danger of wind damage and snow breakage, the more extensive the liberation of the elite tree can be. In other words, the liberation of elite trees with favourable crown formations can be more extensive than that of elite trees with less favourable H:D ratios.

The liberation of elite trees is extremely important in selective thinning. An intervention involving more than just the removal of competitors must take place only if reasons of work organization make it necessary or if a cover rate (timber yield exceeds harvest costs) can be attained. Intermediate hardwood stands should be preserved.

Through liberation of the elite trees or by other removals the remaining trees not chosen to be elite are preserved. Thus when an elite tree is missing, another tree may take its place.

### 3.1.4 Practical remarks regarding selecting

Experience has shown that selection is carried out most effectively in the following way:

- Step one : Determine the harvesting and skidding method;
- Step two : Mark the necessary skid trails (if possible, there should be no elite trees on a skid trail);
- Step three : Select and mark the elite trees;
- Step four : Mark the competitors or in certain cases other trees.

Elite trees are selected only once in the life of a stand. Therefore they should be carefully selected by the district forester, who is assisted by two helpers.

To mark elite trees, plastic tapes may be used; to avoid damage during skidding, these should be removed only after thinning - if at all. Elite trees may also be marked with coloured paint rings or dots. In general, elite trees must be marked to such an extent that they can be easily recognized as such when the next thinning operation is performed.

The trees to be thinned (that is, removed) are also marked for felling by means of plastic tapes, coloured dots, a scribe or an axe.

### 3.1.5 Further selective thinning

Liberation of elite trees should be continued once the crown formation is again restricted. Consistent tending of elite trees at the right time is imperative in order to achieve the highest possible value increment.

When the trees have reached half their rotation age, that is, about 50 years, no further selective thinning or extensive interventions should be carried out. In stands with beech trees, late and extensive interventions could cause an undesirable predominance of beech. Extensive thinning in older stands - where trees are taller - would impair the stability of the stand. Selective thinning which should have been carried out but was not, cannot be made up. It can only be replaced by more careful interventions!

Particularly important!

In stands with a high H:D ratio and thin, poor crown formations thinning must be carried out with great care. Drastic interventions lead to instability of the stand and to damage by snow and storm. Thus only light thinning should be performed in these cases.

4. THINNING OVER THE AGE OF 50  
NO FURTHER EXTENSIVE INTERVENTIONS

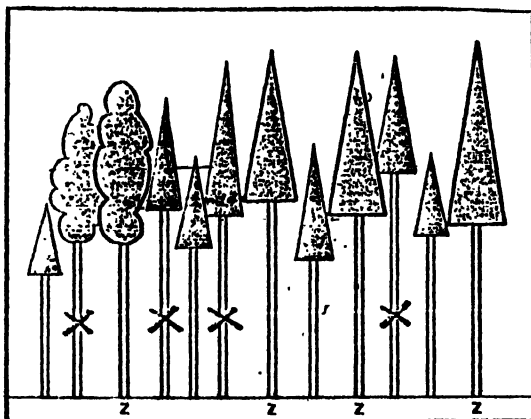
When sufficient growing space for the elite trees has been obtained by means of selective thinning, such interventions are no longer necessary. However, undesirable, badly crowned, damaged or unhealthy trees should still be removed.

Such thinning operations should never or hardly ever be carried out in the crown section. Only light thinning is a practicable alternative. The utmost care must be taken in all late thinning operations.

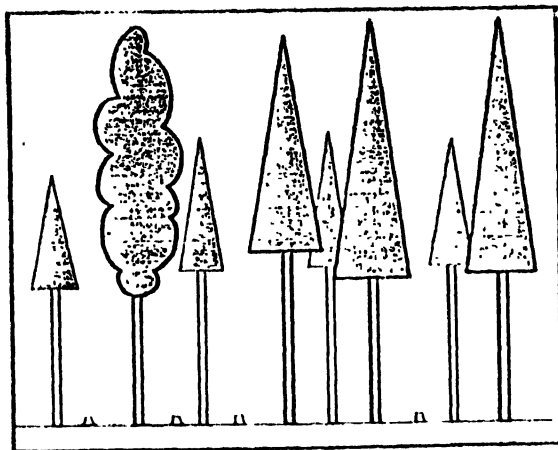
5. SUMMARY OF APPROACH, METHOD AND AIMS OF THINNING

Thin now! Why?

- To ensure the highest yield even from the younger stands.
- To reduce the dissipating effects of competition within the stand and thus promote the growth of the remaining trees.
- To select the most vital, well-formed elite trees at an early date, to constantly promote their development.
- To allow the remaining trees to grow high-quality, uniform crowns.
- To promote the stability of the stand in time and to considerably reduce the risk of damage by snow and wind.
- To attain healthy mixed stands by promoting the varieties of trees which are desirable and suited to the particular location.
- To speed up and increase the value increment of the stand.



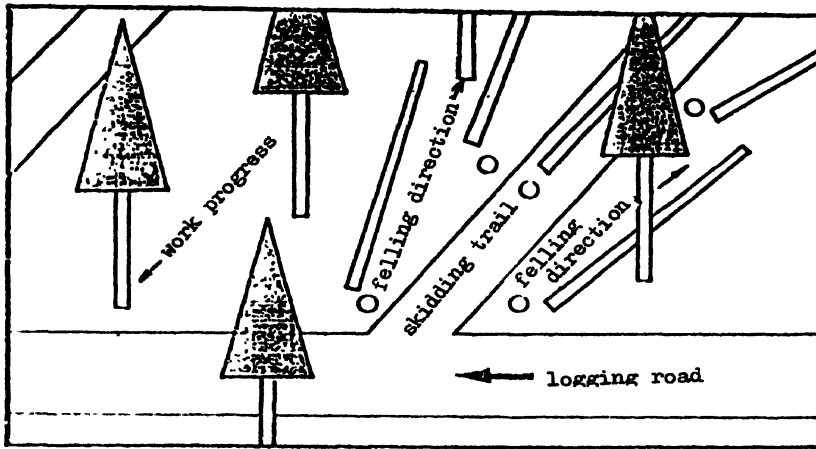
**Selective thinning:  
Promote elite trees  
early.**



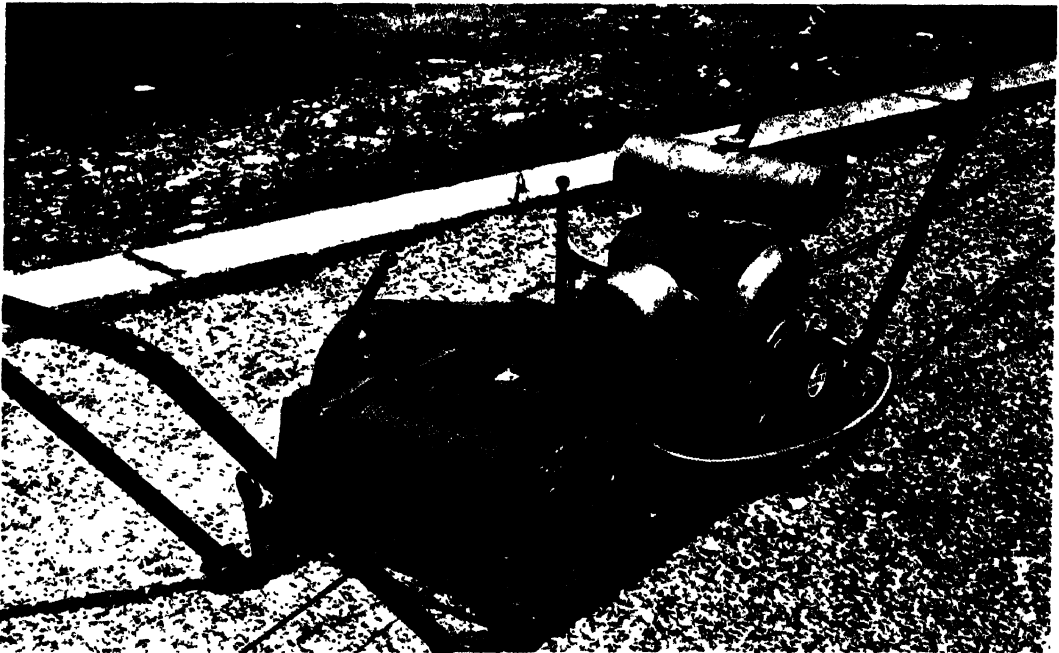
After a few years: a closed, stable stand, full crowns and a higher value.

Thin now! How?

- As soon as the dry-branch zone is 3 to 4 m high, start the first thinning. Thin again when the green crowns of the elite trees are shorter than half the tree length.
- Depending on the growing-space requirements, select 200 to 400 elite trees per ha (minimum distance 4 m) and mark them (colour), then select their competitors (especially unhealthy and damaged trees) for felling.
- In young stands and where tending has begun early, thinning should be carried out extensively. Thin carefully and more often in extremely dense pole-wood stands as well as in middle-aged and older stands (where tending has begun too late).
- Before beginning the operation, determine the area to be thinned, the direction of skidding as well as the storage and handling sites.
- By walking over the area several times, make a detailed survey for further opening up of the area.
- Select approximately 3 m-wide skidding trails with a spacing of 15 - 20 m.
- Carry out felling in the direction of skidding. Fell trees in the skidding trails opposite to the skidding direction; fell trees between the skidding trails at an angle to them.
- When felling, a safe distance of at least two tree-lengths should be observed. Work only with safety equipment (helmet with eye protection, sturdy shoes with skid-proof soles, work gloves, etc.).
- When skidding, the utmost care should be taken to protect the remaining stand. Protect especially exposed elite trees, e.g. by covering them with brush.
- Choice of assortment should be geared to meet the market demands and be adapted to the working procedure. Whenever possible try to sell crane-length logs with bark.



Expert work saves effort and money - greater success



Light weight single drum yarder used for thinning  
(Photo: Federal Forestry Research Institute)



Agricultural tractor equipped with bogie used for transporting fuelwood over short distances (Photo: Steyr)



Articulated wheeled skidder equipped with anti-skid chains extracting large tree-length logs (Photo: Federal Forestry Research Institute)



## BASIC PRINCIPLES OF ERGONOMICS

by

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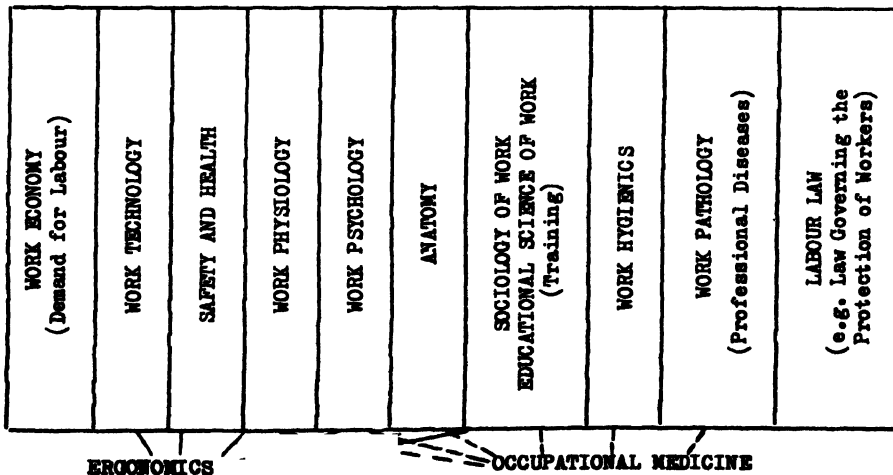
### 1. ORGANIZING FOREST OPERATIONS ACCORDING TO ERGONOMIC MEASUREMENTS

Ergonomics aims at studying and scientifically analyzing the relationships between man and work. Ergonomics is based on experience gained in the most varied disciplines of science. It is a main objective of ergonomics to adapt work to man. In most cases this can be achieved only with the help of ergonomic studies.

In order to adapt work (tools and equipment) to man, the working capacity and energy limit of the worker have to be known. Therefore it is necessary to measure work load, individual physical strain and environmental influences.

### 2. BASIC PRINCIPLES OF ERGONOMICS (according to K8ck)

Terms - Branches of Work Science



<sup>1/</sup> Federal Forestry Research Institute, Vienna

### Definitions

ANATOMY:	theory of the structure of the human body and its parts;
ERGONOMICS:	theory of adapting work to man; man is considered as a component element of a working system;
SAFETY & HEALTH MEASURES:	precautionary measures for the safety of man and material goods
SOCIOLOGY OF WORK:	theory of the interrelationships between work and man on the one hand, and his state of health on the other;
OCCUPATIONAL MEDICINE:	theory of interrelation between work and occupation on the one hand, and man and health on the other;
WORK PHYSIOLOGY:	theory of the functions of the human body and its organs during work;
WORK PSYCHOLOGY:	theory of mental and emotional strain in man resulting from work;
WORK SCIENCE:	theory dealing with different kinds of human work, their interdependence and optimum organization;
WORK TECHNOLOGY:	theory of working techniques (e.g. work studies)

### 3. SYSTEMIZING THE ADAPTATION OF WORK TO MAN

#### Working positions

sitting, standing,  
bending or other

M A N

#### Environmental Influences

artificial and natural lighting,  
colouring, noise, vibration, indoor  
climate (hot, cold), exhaust gas,  
dust, smoke, vapours, etc.

#### Types of Work

muscular work  
(static, dynamic load)  
work under time pressure  
(assembly line, piece-rate, etc.)  
concentrated work

At the work site man is exposed to the influences of his working position and of his type of work, the atmosphere and environment. In addition, psychological and sociological factors come into play.

#### 4. MEASURING WORK LOAD AND PHYSICAL STRAIN

It is the objective of ergonomic measurements to determine the work load of various operations at the work site. The determination of individually tolerable physical strain is of paramount importance. Physical strain on man can be determined through energy expenditure and heart-rate measurements. This is why apart from proper work load studies personal data have to be recorded and special tests (e.g. electrocardiographic measurements) have to be carried out.

Environmental factors exert a substantial influence on the work load. For any ergonomic work evaluation they have to be accurately studied. Since forest work may be carried out under extreme climatic conditions, climate and weather are factors to be studied as well. For wood harvesting in mountainous forests slope gradient and accessibility are two main determinants of work load and work organization. Further determining factors to be examined are work methods, tools and equipment, and protective devices.

All ergonomic research is based on time studies. For accurate results whole-day studies are indispensable.

Mechanization of wood harvesting has created new work load factors which may have a negative effect on the work situation. Here we are concerned with local disturbances (e.g. noise, vibration). Strain induced by exhaust fumes from power saws may, under certain conditions (weather, gradient), be aggravated.

Only a comprehensive study of all these impacts on the worker permits an ergonomic evaluation and organization of wood harvesting.

In view of the above considerations all ergonomic studies are carried out on the following principles: (see Basic Principles of Ergonomics, FAO/Austria Training Course, Ossiach, 1975).

##### 4.1 Obtaining personal data

They include data such as age, weight, size, family status, professional qualifications, medical case history, past accidents and other factors.

##### 4.2 Measuring the circulatory functions

These tests are applied to examine the individual physical strain capacity by means of bicycle ergometers which can be adjusted to different work load rates (PWC 170). The relation between work load and physical strain provides a unit for the individual working capacity.

##### 4.3 Measuring climatic factors

To determine the climatic influences various measurements are necessary. For field studies it is sufficient to measure the wet and dry temperatures by means of aspiration-psychrometers according to Assmann and the wind velocity with an anemometer. The effective temperature is calculated from the values for wet temperature and dry temperature and wind velocity on the basis of a nomogram developed by Yaglou.

#### 4.4 Describing work site, work method, tools and equipment

All factors determining the work method, such as altitude, stand density, stand height, mean diameter, slope gradient, surface conditions, undergrowth and so on, are recorded. For an ergonomic evaluation it is also necessary to study the type of operation (one-man or group work, manual or partly mechanical work, purely mechanical work) and to record and describe the tools and equipment (working and protective).

#### 4.5 Time studies

Our experience has shown that time studies performed under the cumulative timing method have yielded the best results.

#### 4.6 Measuring energy expenditure

Energy consumption is measured with a respirometer or with the Douglas bag. Two different metabolic rates are distinguished, the basic metabolic rate and the metabolic rate of work. To calculate the metabolic rate the amount of oxygen consumed by the worker is measured. This is done with oxygen-analysers.

#### 4.7 Measuring the heart rate

##### 4.7.1 Manual measurement

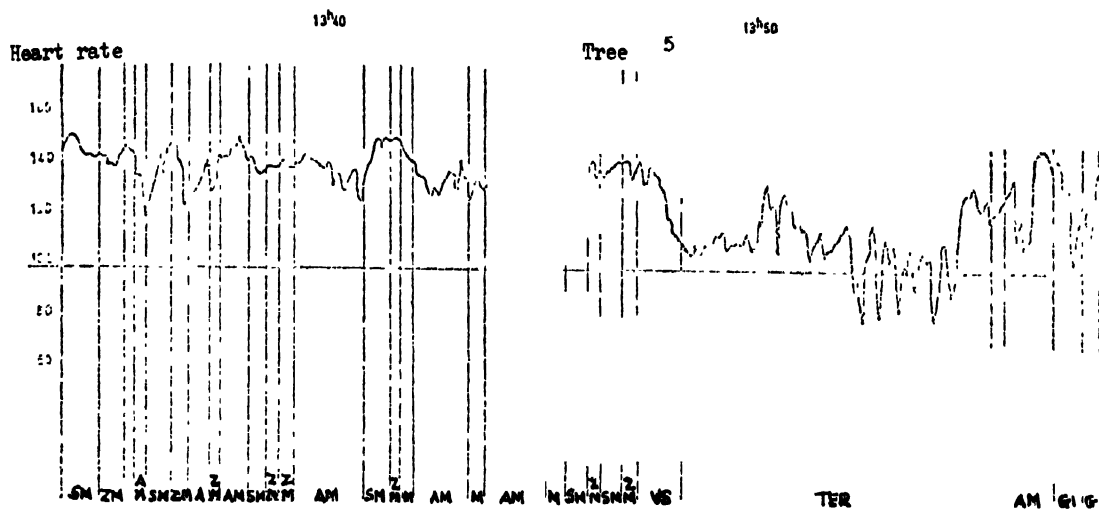
Measurement of the heart rate by hand - feeling the pulse or the carotid artery is carried out by finding the time taken for 10 beats and calculating the heart rate per minute with a stop watch or a special heart rate recording stop watch.

##### 4.7.2 Telemetric measurement

In recent years telemetric recording of the heart rate has rapidly increased. The heart rate pick-ups may be via selenium cells at the ear or chest electrodes (electrocardiogram). The telemetric device consists of a mini-transmitter that is in wireless contact with an automatically recording receiver. This device permits direct counting of the heart beats and also long-term recording of the heart rate diagram (tape or graphic recorder). Scientists at the Max Planck Institute employ the increase of the heart rate during work over the heart rate at rest (initial level) as a criterion of evaluation, whereas Christensen (1953) elaborated a schematic classification of absolute heart rate values.

#### Tolerable Heart rate Values

<u>Heart rate absolute</u>	<u>Physiological load</u>	<u>Increase above initial rate</u>
0 - 75/min.	very low	
75 - 100/min.	low	standing 30 heart rate/min.
100 - 125/min.	moderate	sitting 35 " " "
125 - 150/min.	high	lying 40 " " "
150 - 175/min.	very high	
175/min. +	extremely high	



Section of a whole-day heart rate diagram of a forest worker when felling with power saw.

- AM delimbing with power saw
- ZM pointing with power saw (sniping)
- SM cross-cutting with power saw
- AH delimbing with axe
- A depositing branches by hand in rows
- ZH pointing with axe (sniping)
- W turning logs
- M measuring logs
- G walking without power saw
- G1 walking with power saw
- TER rest period
- VS operational allowance
- VP personal allowance

#### 4.8 Measuring the vibration influence

##### 4.8.1 Noise

The effects of noise are determined by sound pressure, exposure time, frequency distribution, time phases, and individual disposition. Permanent exposure to a marginal noise level of 85 dB (A) may result in impaired hearing. A distinction is made between permanent noise level of constant vibrations and a so-called evaluation level of intermittent vibrations. The term "evaluation level" takes vibration differences as well as pauses in the noise into account.

Noise levels of 85 to 100 dB(A) cause physical and mental impairments and even irreversible damage to hearing (noise-induced deafness). Above noise level of 120 dB(A) the sound pressure affects not only the ear but also circulation, blood supply, autonomic nervous system, etc.

Since nearly all forest machines produce noise levels above the tolerable limit, noise protection in mechanized wood harvesting is particularly important. Active noise protection at the source of noise is sometimes not feasible, particularly in case of mobile machines. In this type of forestry work major emphasis, therefore, lies on the passive kind (ear protection).

Noise measurements carried out in the open cab of various skidders and other logging machines have yielded the following data for loaded and unloaded trips.

	Unloaded trip dB(A)	Loaded trip dB(A)	Frequency range of maximum noise level in Hertz
<b>Wheeled skidder</b>			
- 50	78 - 84	97 - 100	63 - 125
51 - 80	79 - 85	94 - 101	63 - 250
+ 80	80 - 90	97 - 100	250
<b>Articulated wheeled skidder</b>			
- 50	78 - 85	96 - 100	250
51 - 80	79 - 86	97 - 102	125
81 - 110	79 - 88	93 - 100	125
<b>Mobile cable crane with collapsible tower (closed cab)</b>	66 - 78	88 - 98	500 - 1000
<b>Other cable crane installations</b>	88 - 92	102 - 130 (fan brake)	300

Gas detectors are used to determine the quantity of exhaust gas. Gas is absorbed by a suction pump and passes through a filtering tube. The gas concentration in the tube is indicated by a colour spectrum.

## 5. WORK LOAD STUDIES

(Measuring the heart rate during timber harvesting in the mountains).

### 5.1 Felling

New working methods have substantially influenced felling in coniferous forests. In recent years debarking has been increasingly transferred from the forest to industrial plants. Since debarking is no longer always included in the felling operation, one-man forest operations are becoming the rule, and the share of power saw operation time in the overall working time has become much bigger. An ergonomic study of a one-man debarking operation developed by Frauenholz yielded exact data on work load intensity and on power saw operation time for various mean diameters.

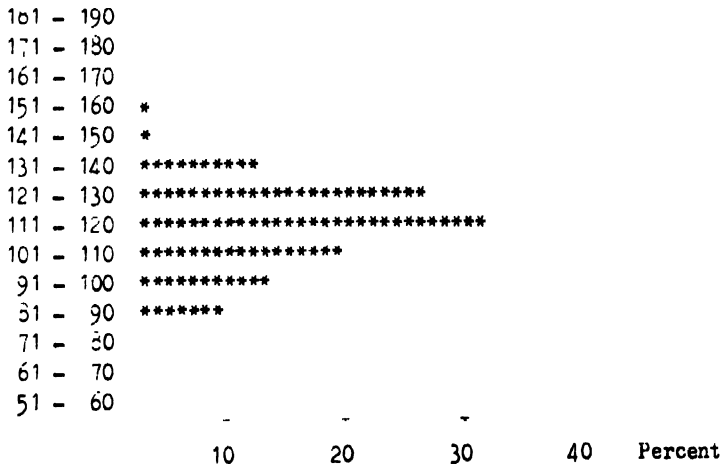


Diagram of the distribution of heart rate frequency (absolute) in the operation of delimbing with a power saw. Average values taken from all diameter classes (mean diameter 9 to 40 cm and above) and four workers (28.7 percent of working time).



Telemetric heart rate measurement in wood harvesting  
(Photo: Federal Forestry Research Institute)



Heart rate increase (absolute) in individual work phases and for various mean diameters

	Up to 19.9 cm diameter measured at breast height		Above 40.0 cm diameter measured at breast height		All diameters measured at breast height	
	time share	heart rate maximum average value	time share	heart rate maximum average value	time share	heart rate maximum average value
<u>Felling</u>						
by hand (FH)	3.52	140	2.05	152	2.70	152
power saw (FA)	5.33	135	8.08	162	6.73	162
inserting wedges (FK)	1.58	139	3.19	157	2.03	160
bringing tree down (FA)	4.92	141	0.10	155	2.20	155
<u>Delimbing axe (AH)</u>	44.60	144	7.51	150	24.00	156
power saw (AM)	14.47	144	37.45	153	28.57	153
<u>Pointing axe (ZH) (sniping)</u>	1.45	145	1.02	154	1.24	162
power saw (ZA) (sniping)	1.23	143	4.27	153	2.86	153
<u>Placement of branches (A)</u>	5.83	144	12.81	151	9.69	151
<u>Turning (W)</u>	1.33	142	5.33	152	2.98	162
<u>Gross-cutting measuring (M)</u>	1.67	142	2.36	155	2.17	155
cutting support (SH)	0.14	143	0.52	150	0.30	150
power saw (3K)	2.23	144	7.66	154	4.54	154
<u>Walking without power saw (G)</u>	3.87	145	3.15	154	3.15	160
with power saw (G1)	7.65	144	3.95	149	6.44	156
<u>Preparing working site (VA)</u>	0.18	138	0.55	139	0.40	148
<u>Working time (TG)</u>	100.00	145	100.00	162	100.00	162
						116

Pointing: simple one-side pointing

Placement of branches: piling on heaps

Overall survey of average day values

	Mean diameter			
	up to 19.9	up to 29.9	up to 39.9	above 40.0
<u>Pure working time (TG)</u>				
minutes per m <sup>3</sup>	58.2	27.3	16.3	14.4
hours TG per day	5.1	4.3	4.5	4.4
<u>Work with power saw</u>				
percentage share of TG	23.1	48.8	53.9	57.5
hours of power saw work per day	1.2	2.1	2.4	2.5
heart rate increase above sitting heart rate, related to TG	42	41	42	47
<u>Allowance percentages (values related to TG)</u>				
operational allowance (T <sub>3</sub> )	3.4	5.6	8.5	8.9
personal allowance (T <sub>P</sub> )	1.3	0.8	1.1	1.0
delay time due to work (T <sub>W</sub> )	1.0	3.8	4.5	2.0
preparation for work (T <sub>R</sub> )	2.2	2.2	2.7	3.2
rest time (T <sub>ER</sub> )	20.8	24.1	20.7	23.4
Sum of allowances in %	28.7	36.5	37.5	36.5
hours of TG+sum of allowances TG	6.5	5.8	6.2	6.0
heart rate increase above sitting heart rate, related to TG	37	35	36	42
share of dead time in TG (dead time= delay due to weather, transport or machine failure) in %	8.5	8.8	4.2	7.1
share of lunch rests in TG	18.4	20.2	22.1	20.7
total allowances' share in TG in %	55.6	65.5	63.8	66.3
total work day in hours (TOTAL)	7.9	7.0	7.4	7.3
heart rate increase above sitting heart rate, related to TOTAL	32	30	31	36
<u>Sum of allowance percentages</u>				
without lunch rest allowance to TG	37.2	45.3	41.7	45.6
hours without lunch rest	7.0	6.2	6.4	6.4

## 5.2 Wood extraction with skidders

Heart rate values measured during skidding operations with skidders in difficult terrain have shown peak work load values for the operator. Substantial heart rate increases were also recorded when storing and stacking operations were carried out with these machines on landings and forest roads (concentration strain). Line-pulling in ground skidding also implies high work load values.

### Ergonomic study of extraction by skidder

Symbol	Work cycle	Time min.	Pulse average	Increase in heartbeats/min above initial level
L	Driving without load	2.8	113	32
H	Hooking up	1.5	115	34
LZ	Pulling the load to the skidder	4.8	130	49
V	Driving with load	2.2	124	43
LM	Storing by skidder	1.5	127	46
LH	Storing by hand	1.0	130	49
H2	Unhooking	2.3	128	47
SM	Handling of the cable	2.4	123	42
P	Personal allowance	2.0	85	4
VS	Allowance (other than personal)	1.5	121	40
		22.0	120	39

## 5.3 Cable crane operations

Heart rate values were recorded during the mounting operation of a cable crane and during various other individual cable crane operations. A marked difference was noted in work load values on cable winch operators and on workers at the felling site and landing.

Of all setting-up operations the most strenuous were climbing up supports, pulling the skyline and setting up the end mast. Winch operation, controlling activity during logging, observing activity, and signalling are below the physiological limit of continuous performance but require high concentration and are affected by noise and sometimes by exhaust gases from the drive unit. Extreme work load values were also found during tensioning of the mainline, when apart from the basic work load, factors of the terrain condition and slope had to be observed. For activities at the landing and during dismantling of the equipment the heart rate increase was negligible.

Work load study of cable-pulling in different terrain conditions

Place	Cable length and diameter	Slope gradient in %	Accessibility	Traction power	Heart rate max.	Increase in heartbeats/min. above initial level
Road	30 m/11.5 mm	flat	very good	150-250	140	48
Road	" "	10% uphill	very good	180-400	148	62
Terrain	" "	42% downhill	holes, twigs & brushwood -bad	150-350	144	50
Road	70 m/9 mm	flat	very good	140-400	168	83

6. INTRODUCTION TO ERGONOMIC CHECKLISTS

Ergonomic checklists help to evaluate working systems and to organize work. In recent years checklists have been compiled by various countries for different applications. Some of them are very general, some serve a detailed purpose.

All checklists are intended as questionnaires based on ergonomic principles and yielding analyses which describe working situations systematically and as completely as possible. Their informative value depends on the questions' scope and precision and on the ergonomic knowledge of the user. A quick ergonomic evaluation is a substantial function of ergonomic checklists.

General remarks on ergonomic checklists

(Quoted from "Checklist for the Ergonomic Evaluation of Forest Machines" compiled by Dr. Rehschuh and Dr. Tzschüchel, Mitteilung des KWF\* - volume XIX, 1977.)

The checklist is intended for an ergonomic evaluation of forest machines and was elaborated and compiled by the work economic department of the KWF (Board of Forestry Works and Techniques, FRG). It is based on experience gained in applying the first and second drafts and other domestic and foreign checklists and it was discussed with various authorities. Application of the present checklist requires ergonomic knowledge; it is recommended for use by institutions such as testing stations for forest machines, by supervisors of forest machine and forest technology centres, by designers of forest machines as well as for educational purposes.

The checklist is designed for the evaluation of forest machines - with the exception of portable power devices - and consists of a questionnaire and explanations. The explanations are meant to make answering easier and to allow general standards to be applied to the answers. International standards are included as far as they are known and applicable.

\* Board of Forestry Works and Techniques, Federal Republic of Germany.

Since only some evaluation items are standardized the explanations contain reference values which are taken from publications in technical literature. These values are related to standards and regulations applied in the Federal Republic of Germany and must be adjusted for use in other countries. The values given correspond to the present state of work study findings, and updating is necessary.

The checklist is divided into three parts:

Part A is intended as a general description and includes checking and description of the machine, and technical data.

Part B is the main part and contains the individual questions for the ergonomic evaluation. The appropriate column is checked off (+, 0, -). If the question does not apply, this has to be indicated by the entry "not applicable".

Plus answers to the questions in Part B lead to the assumption that the solution is ergonomically favourable; minus answers indicate an ergonomically unfavourable judgement. The questions are not listed according to importance.

Part C contains a summary and recommendations. If the ergonomic utility of a machine is to be judged (for example for comparison with other machines) it may in some cases be enough to answer the questions in part C, which should, therefore, be carefully completed.



Heart rate measurement by hand, with stop-watch  
(Photo: Federal Forestry Research Institute)



Measuring the concentration of gas with a gas detector  
(Photo: Federal Forestry Research Institute)

THE USE OF TELEMETRIC AND COMPUTERIZED ERGONOMETRIC MEASUREMENTS  
FOR DETERMINING AND EVALUATING PHYSIOLOGICAL PARAMETERS  
IN MECHANIZED WOOD HARVESTING

by

Josef Jencel  
Forstliche Bundesversuchsanstalt 1/

Several years ago the pulse telemeter, invented by Friedberger and Laczinski of Austria, was further developed by the Austrian Society for Occupational Medicine. For some years now the Institute of Forest Technology of the Federal Forest Research Institute has been using this telemeter for conducting ergonomic studies (i.e. pulse-rate measurements) of partly mechanized timber harvesting<sub>2</sub> operations. The receiver and the integrator of the receiving station are linked to an XY <sub>2</sub> recorder, which monitors the pulse rate of the test individual during the entire observation period. The pulse rate is monitored by means of a photographic cell attached to the ear of the test individual.

This instrument has proved excellent in all cases where the distance between the transmitter and the receiver is short. As a result of the low transmitter output it is not possible to conduct ergonomic studies over longer distances. For this reason, the stress studies carried out by the Institute concentrated primarily on felling operations.

Acquired data were computed and evaluated with the aid of slide rules and conventional calculators and the values thus obtained were subsequently compared with nomograms. As a great number of data had to be routinely monitored, the time input for evaluations and formulating test results was considerable.

In view of the ever greater mechanization of wood harvesting operations, the need arises to draw up physiological profiles of work phases so as to be able to determine the stress to which people operating forest machinery, such as articulated wheeled skidders, processors and conversion equipment, are exposed. For this purpose a telemetric unit is now used which is capable of transmitting the operator's pulse rate to the receiver over longer distances. In addition, this unit simplifies the data evaluation process because it is linked to a computer. The recent advances of space and satellite technology have also led to an enormous reduction in the size of electronic components. Consequently, telemetry (i.e. the transmission of electrical data by wire or by radio) is increasingly used in the field of biology and medicine.

In principle, telemetric equipment functions as follows: sensors monitor a physical process taking place in the object (subject) being observed and transform this into a signal by means of a data conditioning module. In a multiplexer, which permits intermittent data retrieval, several data channels are modulated to one channel. For the transmission of data from the transmitter to the receiver, an ultra-high frequency band is normally used. The data are first demodulated and decoded and then fed into recording or visual display units for evaluation.

This type of mobile measuring, transmission and evaluation equipment has meanwhile become an indispensable aid to occupational, flight, intensive care, sports and traffic medicine, as well as to cardiological rehabilitation practice. The mobile systems must be capable of recording accurately and continuously the physiological and physical parameters of freely moving patients/subjects and control persons. They offer the technological basis for long-term studies over distances of varying length, for simultaneous monitoring of several controls and for multi-factorial recording of several parameters. Moreover, they provide reliable data, which can be retrieved at any time.

1/ Federal Forestry Research Institute, Vienna  
2/ Recorder with horizontal axis (x)(abscissa), and vertical axis (y) (ordinate)

The telemetric equipment described above was produced by Messerschmitt-Bölkow-Blöhm (MBB) Company Ltd., Munich, and is marketed under the name Monitel 2. The equipment is based on a frequency multiplexing system which permits the accurate transmission of data and which is reliable in operation.



Telemetry and ECG <sup>1/</sup>equipment built into a Volkswagen bus. (Photo FBVA <sup>2/</sup>)

Twenty-seven separate high-frequency channels of the 433 MHz <sup>3/</sup>band are available for the wireless transmission of two parameters for synchronous monitoring.

The telemetry system consists of a small transmitter and a module-type receiver. Its compactness and low weight facilitate the mobile use of the transmitter, which imposes no physical strain on the test individual. The transmitter may be put in a pocket or attached to a protective helmet or belt. The pulse rate is measured by means of chest electrodes and the recording resembles an electrocardiogram (ECG).

The telemetry system Monitel 2, offers a wide range of applications going beyond pure ECG monitoring. When suitable transmitters and monitoring instruments are used, other parameters such as the respiratory rate, the skin surface temperature, etc., can be monitored and transmitted by radio. Depending on terrain conditions, the operator's bio-functions can be monitored over a range of several kilometres. A commercially available set of batteries permits continuous operation of the transmitter for at least 30 hours. The receiver is a separate 19-inch unit. In addition to the oscilloscope a number of other instruments may be linked to the telemetry system. Electrocardiographs, tape recorders or analogous digital converters permit further monitoring and signal conversion.

The entire equipment in use by the institute is built into a Volkswagen bus and is therefore fully mobile. The Federal Testing Centre for Agricultural Machinery at Wieselburg/Erlauf, Lower Austria, integrated the measuring, storage and evaluation equipment and did an excellent job of designing the work place of the testing equipment. Power is supplied

<sup>1/</sup> Electronic data processing

<sup>2/</sup> Forstliche Bundesversuchsanstalt (Federal Forestry Research Institute)

<sup>3/</sup> Megahertz



by a fuel-engine type generator via accumulators and transformers so that a 220 V alternating current is obtained. A telescoping antenna assures trouble-free reception within the operating range. A Digital Equipment computer, model PDP 11/03, system R11, serves as evaluation unit.

Using this computer the ECG and the respiratory rate of a test individual can be transmitted via a dual-channel transmitter, and at the same time the work cycles observed by a work study expert can be transmitted by means of a second single-channel transmitter. A further expansion of the equipment is planned to monitor simultaneously the biodata and the time study results of four test persons.

The electronic data processing equipment offers a number of advantages for data acquisition and evaluation. Thus the testing staff is relieved of the extensive and time-consuming calculation work, human error is reduced to a minimum, the test results are obtained more rapidly, the information volume is enlarged. Furthermore, the automatic print-out assures a speedy calculation of test results, which are more easily reproducible, the comparison with standard values as well as recording and filing of test results are automatic and data retrieval for statistical use is rapid.



Audiometer used to detect hearing losses (Photo: T. Pasca)



Single drum yarder winching itself uphill through the forest (Photo: R. Heinrich)

## TIME STUDIES FOR SKIDDING OPERATIONS

by

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### 1. INTRODUCTION

Time studies for skidding have three functions: planning, execution and evaluation, with the main emphasis on the first two. Evaluation is a process of simple calculation dictated by the purpose of the time study. Time studies should be carried out only by trained people.

### 2. PLANNING

Time studies for skidding performance data (time required per unit). From this data the rate of utilization (frequency) and economic return of a machine, as well as labour productivity, can be determined. They also form the basis for calculating the cost of skidding, therefore good planning of skidding operations. The purpose of time studies should be clearly specified.

#### 2.2 Requirements

Before time studies are started, there should be a basic agreement between management and employees that they are needed.

Skidding personnel should be trained; they should be familiar with their tools and machines.

The conditions of tools and machines should be checked first of all, and possible defects eliminated to guarantee smooth operation and to prevent accidents.

#### 2.3 Preparatory work

Both the work process in general, and individual skidding operations should be surveyed. The scope and limits of individual operations should be determined so that the proper time required for each operation can be estimated.

The characteristics of the terrain are identified and classified according to slope gradient, topography, soil conditions, stand density, and so on. The time taken to drive equal distances in differently shaped terrain is measured.

### 3. EXECUTION

Since human labour, mechanical tools and machines will be observed, whole-day studies are advisable. The duration of the observations depends on the purpose of the study; it may last for a week or longer.

The number of people carrying out time studies is dependent on the timing method chosen and the type of units to be observed (people, tools, machines). They should have all that

they need, such as stop watches, time sheets, forms, etc. Short test studies are carried out, after which necessary adjustments are made, and the study can start properly.

### 3.1 Methods of timing

There are various methods used in conducting time studies for skidding.

#### 3.1.1 Cumulative timing

This method is particularly suited to illustrate the working process, since the time required for each work unit or group is recorded as well as the time of the day. With the help of such a record it is easy to discover periods when machines are idle or people are waiting, situations that usually occur when several work groups are combined. Necessary adjustments in work can thus be made.

#### 3.1.2 Partial operation timing

This method is applied when a chronological recording of the work process is not necessary.

The absolute times required for each work unit or group are recorded on the form. These entries are already made under their respective headings so that they can easily be summed up and evaluated. This method requires a profound knowledge of the work process.

Both the above methods require a relatively large number of timers, usually one timer per worker.

#### 3.1.3 Observation ratio method

In this method 11 operations carried out by a worker are coded with a symbol and recorded at certain intervals (usually once a minute). Although the resulting values are not absolute, the accuracy of the time requirements for each operation unit is sufficient if enough recordings are made. Evaluation is carried out by summing up equal symbols. The total time requirement of an operation unit is usually expressed as a percentage.

It is an advantage of this method that one timer can observe several workers or machines within the chosen interval.

### 3.2 Determination of volumes and special working conditions

In order to determine the time requirement per unit of wood volume, it is necessary to find out the amount of timber that is skidded. This is done by measuring the logs (diameter and length) and sometimes also by judging their quality. In the case of animal skidding, mechanized skidding and cable extraction, the volume of timber is measured for each individual load so that comparative values can be determined.

As in different terrain lateral skidding to the main track is rather time-consuming, distances and terrain characteristics have to be recorded either in average values or individually for each skidding operation. It is also important to know the weather conditions and changes that influence the time required.

## 4. EVALUATION

Evaluation may be by calculation or computerized analysis if a sufficient amount of data is recorded. If a computer is to be used, this factor should be taken into account at the planning stage to avoid wasting time in making appropriate adjustments to the data recordings later on.

## WORK STUDIES IN FORESTRY

by  
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### 1. INTRODUCTION

The aim of work studies is to increase the profitability of an enterprise with due regard to the capabilities and needs of the workers; to streamline the work (to get more output of work with less physical input, within a shorter time); and/or to streamline through mechanization (or using the right machine at the right time in the right place).

The elements in work studies are as follows:

- Time studies and data collection
- Stress studies
- Methods studies
- Workplace studies
- Cost calculations
- Organization of work
- Instructions for work

### 2. TIME STUDIES AND DATA COLLECTION

#### 2.1 Time studies

Time is in many respects a significant indicator of the efficiency of work. Using time as a criterion, all operations can be analyzed, described and optimized. Time plays a significant part in an analytic organization of work. It serves as a yardstick for efficiency and forms the basis for any further considerations such as establishing a norm or making improvements.

Performance is always expressed in terms of time (performance in time units, for example, cubic metres per hour; or time requirement per unit, for example, x hours per cubic metre).

Stress is studied by measuring the pulse rate or the joule/calorie input per time unit.

Costs are determined on the basis of machine time or operator time required for each unit.

Work methods are analyzed for the time required for each phase of work.

The workplace is studied by observing the time input, stress and the flow of work under varying conditions.

For work organization the time input, strain on the worker and costs of different procedures are compared.

The time input is required for determining the standard times required to perform a function.

### 2.1.1 Time as a factor of workflow

A distinction is made in time studies between:

- a) operator time (that is, the time the operator needs to complete his task, time input of wage earners and salaried employees)
- b) machine time (the time taken for utilization of equipment: machinery, tools, plant, installations, facilities, and so on), and
- c) materials time (the time required for materials, supplies and objects which are to be produced, extracted, shaped or worked in the course of the work process).

Operator time may be subdivided into direct and indirect active time, and waiting time.

Machine time consists of the controlled running time, secondary running time and dead or down time.

Materials time comprises the time needed for working the materials, handling time and idle time.

The relationship of the individual time categories may be seen when they are set out as follows:

OPERATOR TIME	active time		waiting time
	direct	indirect	
MACHINE TIME	controlled running time	secondary running time	down time
MATERIALS TIME	processing time	handling time	idle time

Only a very accurate definition of the above time concepts and an exact breakdown of their shares in the work process will supply significant information on the efficient and economic use of time. The results of a time study will help to determine the accuracy of the breakdown.

Although an approximate estimate of the time input gives an idea of the performance achieved in the time unit or the time input required for each unit, it fails to show how the work was carried out.

### 2.1.2 Time categories

#### Genuine working time (GWT)

Genuine working time is defined as the time which can be directly attributed to the work sequence, that is, time required for the execution of the job.

This time category may be broken down further:

operator time: into main activities as well as stoppages necessitated by the sequence of work (that is, waiting or walking)

machine time: into controlled running time, secondary running time and stoppages necessitated by the process (that is, waiting).

### General time (GT)

This comprises delay allowances, rest time and start-up or shut-down time. Such time categories are due to the individual needs of operators, the requirements of the job or organization.

Job-related allowances: filling fuel in the tank of the vehicle, sharpening tools, minor repairs such as adjusting the carburettor, tightening screws, and so on.

Personal allowances: for changing work clothes, blowing nose, and other personal needs.

Organizational allowances: discussions with the district forester or the supervisor of a job, coordinating teamwork, and so on.

## 2.2 Data collection

### 2.2.1 Categories

The following are the categories of data collected:

Time: the time required for each sequence and expressed in 1/100 minutes, minutes or hours; the time required for each unit, time required for each cycle, time required for each process.

Reference quantity: the result of the work carried out in each cycle within the specified time. Reference quantity may be expressed in cubic metres, pieces, distance or length, surface area.

Determinants: the factors influencing the time required for the reference quantity and showing the conditions under which a certain performance was achieved. Such determinants are, above all:

machinery and equipment, workplace characteristics, weather, work sequence, work procedure and work flow, work methods, the state of the work object, quality requirements and the operator's capabilities.

### 2.2.2 Data application

Data provide the very basis of decision-making in all matters relating to:

- a) the planning and organization of work
- b) the choice of work procedures
  - comparison of procedures, determination of the effectiveness of work methods, machinery and equipment
  - stress studies
  - cost calculations
- c) payment of wages and salaries
  - determination of standard time, premiums, wage grades, etc.
- d) supervision
  - checking performance, recalculations
  - checking operating results of the enterprise.

The amount of data gathered depends in each case on their application. In some instance it may be sufficient to get a general orientation from the data, whereas in other cases a detailed analysis is necessary, such as in setting the standard time required for the specific job, phase or function.

### 2.2.3 Time observations

The time observed is expressed in 1/100 minutes, minutes or hours for each cycle, and calculated for each unit and work process.

### 2.2.4 Time formulae

#### 2.2.4.1 The continuous reading method (cumulative timing)

The time is taken and recorded at each reading point; the time differential equals the duration of the relevant sequence.

Advantages: The work sequence can be reconstructed; reading or recording errors may be identified afterwards; only a simple stopwatch is needed.

Disadvantages: Individual time elements must be computed; only one operator or one machine can be observed at a time; short sequences can be recorded only with difficulty; for each time value the sequence must be described.

#### 2.2.4.2 Flyback timing method (snap-back method)

For each sequence the stopwatch is set to zero. A distinction is made between the method using observation sheets and the same method without observation sheets. In the former with all individual time values entered on an observation sheet, the advantages and disadvantages are as follows:

Advantages: No calculation of time differentials, description of sequences not needed.

Disadvantages: The work sequence cannot be reconstructed; reading and recording errors are difficult to identify and can be spotted only within each control sequence. A special stopwatch is needed. Only one operator or one machine can be observed at a time.

In flyback timing without observation sheets, the individual time values are recorded consecutively, as in the cumulative timing method.

Advantage: more rapid evaluation, since time differentials need not be calculated.

#### 2.2.4.3 The ratio delay method (activity sampling or multimoment)

Time inputs are not observed, but the frequency with which an activity occurs within a sequence is determined. Every 50/100 minutes or every minute the number of repetitions of an activity are recorded. As a rule, observation sheets are used.

Advantages: One work-studies expert can observe several operators and/or machines simultaneously. Short sequences are recorded in a representative form provided the time studies are conducted over a sufficiently long period. An accurate observation of reading points is not needed. A simple watch or stopwatch suffices.

Disadvantages: The work sequence cannot be reconstructed; reading and recording errors can be traced back to the last control section.



### 2.2.5 Checked time

In order to be able to check recordings, time studies must be sub-divided into control sections. The difference between the positions of the hands on the watch at the beginning and at the end of the control section, corresponds to the checked time (standard time). The sum total of all individual time values for the overall control section (actual time) may amount to + 3% of the standard time in the case of operator time, and + 5% for machine time. Errors which do not exceed the above percentages are distributed over the sequence. If errors exceed these percentages, the values taken for the sequence cannot be used.

The reference quantity is determined for each cycle. A cycle may be: felling a tree or a trip (empty travel of a vehicle, turning, pulling out the line, drawing the load toward the vehicle, loaded trip, detaching the load, storage of load, turning), or a certain area (cleaning a young stand, reafforestation).

Reference quantities: Cubic metres harvested with or without bark, number of trees, distances and size of area.

Determinants: These are recorded and described for each cycle.

- a) Workplace: soil characteristics, soil surface, soil cover and ground vegetation, vines, thickness of snow cover, etc.
- b) Work procedure, work sequence and methods.
- c) Operator (age, training, capabilities).
- d) Machinery and equipment (detailed description indicating dimensions, weights, performance rating).
- e) Object of work (e.g. tree shapes, dimensions, branching, sap, etc.).
- f) Weather (temperatures, precipitation, cloud cover, etc.).

All these factors influence performance. Some of them can be quantified, measured or counted, whereas others can only be described in a general way.

The time values determined through time studies are referred to as "actual time". For determining standard time a performance rating of each individual work sequence must be made.

### 2.3 Standard performance and efficiency

#### Definition

Standard performance, arrived at through time studies with efficiency rating, is defined as the type of motion which the observer considers particularly harmonious, natural and well-balanced in terms of individual movements, their sequence and coordination. Experience has shown that standard performance can be reached by any worker who is capable, adequately trained and completely familiar with the job. This performance must be maintained for extended periods and be reached by all of the workers taken on an average, provided the breaks arranged for personal needs and for rest, as required, are taken and operators are not hampered in the development of their capacities.

The ratio between the observed actual performance and standard performance expresses the efficiency. An efficiency of 100% corresponds to standard performance, a 120% efficiency means that the observed performance is 20% above standard performance.

## 2.4 Average performance

Instead of standard performance, average performance may be used for various purposes. Average performance refers to that achieved by a group of workers or a set of machines and can be expressed as a certain value.

## 2.5 Auxiliary equipment for data collection

Stop watches "addition" type, zero stoppers, zero stoppers with speed indication, a combination of watches, electronic chronometers.

Prerequisites they should be easy to read, and have a "jumping" minute hand, hour hand and recorder attachment.

Writing pad with attachment for observation sheets, compartment with pigeonhole to hold paper (so that the work-studies expert has his hands free).

Observation sheets (job description sheet, time record sheet, reference data sheet with determinants).

### Compilation of data

#### a) Planning

- Define work process
- Describe work procedure, work sequence and methods
- Describe the job to be carried out
- Define minimum standard of work quality
- Define the duration of time study
- Select time formulae
- Choose data relating to reference quantity
- Decide whether determinants are to be quantified or described as regards their quality
- Consider natural performance rhythm

#### b) Preparation

- Inform personnel, management, obtain consent from labour unions to use data as a basis for pay
- Select workers, work places, as well as machinery and equipment to be observed
- Put up distance markers, carry out preliminary surveys of reference quantities and determinants
- Instruct and inform operators on work and pay
- Hold a trial run, observe work flow and subdivide process into sequences; select reading points and control sections
- Prepare observation sheets, check or obtain all instruments and other equipment needed for the time study
- Instruct assistants or work study experts
- Carry out test studies

#### c) Carrying out time studies

- Carry out whole-day studies, observe time inputs of each sequence, record reference quantities and determinants in each cycle indicating the control sections
- If necessary, perform efficiency rating.

## 2.6 Evaluation of recorded data

- i Calculate time requirements for each sequence
- ii Calculate reference quantities
- iii Compute time elements, evaluate actual and standard time values
- iv Calculate time input of each unit and rate performance
- v Interpret results.

#### Ad. i) Calculation of time values

In the continuous reading method time inputs are calculated by subtraction. In the ratio delay method, the entries are counted for each sequence. The computed or recorded time values are compared for each control section.

Tolerances may be varying depending on the purpose of the time study. The observations made for a control section are insignificant if the actual time values do not exceed 3 percent of the standard operator time and 5 percent of the standard machine time.

Errors of less than 4 or 5 percent respectively are distributed over the entire control section. Minor deviations from the standard may be disregarded in some instances if these do not affect the purpose of the time study. If the activity sampling method is used, the time input for the control section may be divided by the number of entries. The time value thus established is then multiplied by the number of entries for each sequence.

#### Ad. ii) Calculation of reference quantities

It is advisable to enter the determined reference quantities (cubic content, number of units, surface areas) and perhaps also significant determinants (such as distances, in the case of conveyance jobs) for each cycle in the evaluation list.

#### Ad. iii) Determining time categories

Before the time input is recorded for each sequence, the time category (i.e. genuine working time, basic or general time) must be determined.

#### Evaluation of actual time

As a rule, only the real working time (basic time) is used for assessing actual performance. General time is taken into account in the evaluation only if the time study is extended over a long period and if it occurred typically at irregular intervals. All time categories are added up and the resulting sum total is then expressed as a percentage of standard time; for each cycle, the percentage thus computed is subsequently added to the standard time.

Total actual time (real working time plus general time) is then used for calculating actual performance within each time unit or for determining the actual time required for each unit.

When shorter time studies are made, only the recorded basic time values (real working time) are used and general time is added as a percentage calculated on the basis of empirical values. Empirical values are obtained from time studies or assessed through allowance studies. If the work continues beyond the maximum tolerance limit, adequate recovery allowances must be provided. These are calculated on the basis of stress studies.

#### Evaluation of basic time

The actual basic time inputs are multiplied by the performance factor (efficiency over 100) and entered on the evaluation sheet for basic time. General time is expressed as a percentage and added to basic time on the basis of empirical observations. The time required per unit or the performance within each time unit is related to basic time and overall time required is computed for each cycle.

If the percentages of an ideal breakdown of time elements (according to REFA <sup>1/</sup>) are known for a job as a result of stress and allowance studies, the ratio between general time and basic time may be computed.

#### Time study diagram

The time study is graphically expressed in the form of a "tree". The subdivisions chosen depend in each case on the purpose of the study.

1/ Procedures for time studies as set down by a German organization dealing with time studies.

## 2.7 Interpretation of results

### Calculation of the mean value, the standard deviation, and the variation coefficient

#### The mean value

$$\bar{x} = \frac{\text{sum-total of all time value per cycle}}{\text{number of cycles}}$$

As a rule, the mean value is calculated for basic time, in skidding operations only for a certain distance; in felling only for trees of the same diameter.

#### Standard deviation

The standard deviation is calculated using the equation below:

$$s = \sqrt{\frac{1}{n-1} \cdot (\sum x^2 - \frac{(\sum x)^2}{n})}$$

n = number of all observed data (series of readings)

x = sum total of all observed data

x<sup>2</sup> = sum total of the square of observed data

s = standard deviation

#### The variation coefficient

The variation coefficient is the percentage of standard deviations from the mean value

$$V_c = \frac{s}{\bar{x}} = \%$$

See example on the following page

The standard deviation indicates whether a mean value is representative of the observed conditions and to what extent it permits a generalization. There are no general rules concerning the maximum permissible standard deviation or variation coefficient; the size of the mean value and the purpose for which it is to be used are the basic criteria. Overall working time, actual working time required for each cycle or phase.

### Correlation of data

By using a system of coordinates and plotting the observed or computed time values, the correlation of data can be illustrated, that is, the time requirement for one trip may be plotted on the y-axis, and the distance covered in one trip on the x-axis; the time input for each cubic metre of felled wood indicating mid-diameter and diameter at breast height.

### Evaluation of non-quantifiable determinants

For all computed or graphically represented data all influencing factors which cannot be quantified, such as the characteristics of a skidding path, or conditions which result in excessive time inputs (if a tree gets caught during felling, for example) must be described.

As a matter of principle, time studies which are made so as to be able to fix standard time must be carried out with maximum responsibility and care. The question as to whether a value is representative or not should be studied with utmost concern.

Example for determining the mean value, the standard deviation and the variation coefficient.

Whole-day study carried out during thinning, assortment felling of 95 trees, of which 16 had a mid-diameter of 10 cm. The basic time required is expressed in minutes.

	$x^2$
5.44	29.59
3.69	13.62
4.94	24.40
4.93	24.30
3.59	12.89
3.43	11.76
4.23	17.89
3.33	11.09
3.60	12.96
4.30	18.49
4.35	18.82
3.07	9.42
3.64	13.25
4.41	19.45
3.89	15.13
<u>4.96</u>	<u>24.60</u>
65.80 $\Sigma x^2 =$	277.76

$$\text{mean value } x = \frac{\Sigma x}{n} = \frac{65.80}{16} = 4.11 \text{ minutes}$$

$s$  = standard deviation

$$s = \sqrt{\frac{1}{15} \cdot (\Sigma x^2 - \frac{(\Sigma x)^2}{n})}$$

$$= \sqrt{0.066 \cdot (277.76 - \frac{4329.64}{16})}$$

$$= \sqrt{0.47256} = \pm 0.69 \text{ minutes}$$

$V_0$  = variation coefficient

$$V_0 = \frac{s}{\frac{\Sigma x}{n}} = \pm 17\%$$

### 3. TOLERANCE TESTS

Work imposes various types of strain on man.

#### 3.1 Physical strain: dynamic or static work, walking in the terrain.

Physical strain may be determined manually or by telemetric measurements carried out while the work is being performed.

Based on a daily working time of eight hours, the maximum tolerable stress limit is reached when the worker's pulse rate increases by 35 beats per minute over the initial pulse rate (pulse rate at rest, sitting). When continuous stress exceeds this limit, breaks have to be arranged in such a way as to ensure that the maximum increase of the pulse rate of 35 beats is not exceeded. Short breaks are arranged as needed until full recovery is reached (that is, until the pulse rate is approximately normal).

#### 3.2 Strain induced by environmental factors (weather, noise, vibrations, exhaust fumes, etc.).

Strain due to these factors must be assessed and reduced to a tolerable limit or avoided through adequate protective measures.

**Weather:** protective clothes, mobile shelter at the workplace, proper timing in the organization of work (with due regard to season).

**Noise:** active noise protection above a noise level of 90 decibels (earplugs or muffs, noise insulation) or noise reduction through adequate technological measures. Reduction of strain due to organizational measures (e.g. selection of work procedures, sequence of operations, work methods).

Vibration, exhaust fumes: technical improvements, shortening of exposure time by means of organizational measures.

#### 4. SEQUENCE OF OPERATIONS

The sequence of operations is observed and its positive and negative effects on the operator and his performance described, analyzed and, if necessary, corroborated by time studies.

#### 5. STUDY OF THE WORKPLACE

The workplace is analyzed for its suitability for certain types of work: here the time input, performance, stress and industrial safety are criteria for evaluation. If necessary, various elements of the work process may be shifted to another workplace which is more favourable for the specific task.

#### 6. COST STUDIES

For work studies, the direct sectional costing method is primarily used (target costs: costs per unit under certain circumstances; wage costs and costs for machinery and equipment).

#### 7. WORK ENGINEERING (SYSTEMS ENGINEERING)

Work engineering aims at the selection of the optimum system of work (procedures, machinery and equipment, sequence of operations, work methods, object of work) in terms of performance and a humanized workplace, under given influencing factors (standard terrain characteristics, number of persons available for the job, etc.) and at an improvement of the profitability of the forest enterprise.

Work engineering is based on studies of time, stress, work flow, workplace and costs.

##### 7.1 Analytic work engineering

The work engineer observes processes, gathers data such as the time input, the reference quantity, determinant factors and costs per unit, evaluates these and adjusts the system of work or individual elements of it to the envisaged goal or process.

##### 7.2 Synthetic work engineering

The work engineer uses conventional processes and work elements to synthesize these into a work system.

As a rule, the two work engineering methods cannot be separated from each other; normally both methods are used alternatively in the elaboration of a system of work. Work engineering is a continuous process, in which work is geared to technological developments, the requirements of the market and the labour, as well as biological needs.

#### 8. WORK INSTRUCTION

Instruction for work must consist of explaining the processes to the person involved in carrying out the job.

Instruction may mean learning something new, learning something better, or learning to do something in a different way. Among various instruction methods the four-phase method has proved very useful:

- Phase one: acquainting the operator with the process (arousing his interest, demonstrating, discussing the job)
- Phase two: the trainee tries to carry out the process under the guidance of the instructor
- Phase three: the trainee repeats the process several times thus practising what he learnt in phase 2. If necessary, he is corrected
- Phase four: no further practice needed, perfection of skill.

#### DEFINITION OF TERMS

##### Work procedure

Work procedure is defined as the technological way to reach the objective of a job.

In forestry it is common practice to name the procedure after the state in which timber is logged, as this indicates the technological method used.

Assortment method - felling and conversion into assortments at the felling site, using power saws  
- transporting the assortments to the logging trail by means of wheeled tractors, articulated four-wheel-drive skidders, cable cranes, or manual skidding, etc.

Full-length method - felling, delimbing of the upper log side at the felling site, using a power saw  
- transporting the logs to the conversion site or to the logging trail by means of a skidder  
- conversion (bucking, final delimbing by means of a power saw)

Whole-tree method - felling by means of power saw  
- transporting the trees to the conversion site or to the logging trail (skidder)  
- mechanized conversion using processors (delimbing, bucking, debarking)

Fully mechanized method - felling and conversion at the felling site, using processors (combining a variety of technological procedures).

##### Work sequence

##### In terms of organization

What must be done?

At what time? (i.e. timing of operations)

Where? (i.e. workplace)

Individual processes must be identified and a decision taken as to whether these are to be carried out simultaneously or one after the other, at different places or in one place, e.g. in working the log: closed or open chain of work?

##### In terms of technique

How is the work to be done?

The sequence of operations is laid down and described (work method).

### Work method

This is defined as the sequence of operations which is accurately specified, if necessary broken down into individual work elements, and which depends on the technique, the machinery and equipment as well as the materials and supplies used by the worker.

The work method can be observed and specified by means of job analyses and can be taught to trainees.

### Working techniques

This is the individual approach to the work process using a given work method and varying from one person to another. In many cases it can be fully understood only after the job is broken down into work elements and the "micro-sequence" is analyzed. Working technique is expressed in terms of efficiency of the operator.



Loading a logging truck with a truck-mounted grapple loader  
at the log landing (Photo: E. Pestal)



ANNEX I

COURSE PROGRAMME

- Monday, 1 June**
- Arrival at Klagenfurt Airport (via Vienna Schwechat Airport)
  - Transfer by bus from Klagenfurt Airport to the Forestry Training Centre, Ossiach
  - Registration and information
  - Accommodation in hotels and guest houses
- Tuesday, 2 June**
- General information at the Information Desk in the Club Room of the Forestry Training Centre, Ossiach
  - Official opening of the Training Course in the Rittersaal of the Stiftshotel, Ossiach
  - Welcoming speech and introduction to the Course by Ir. H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry
  - Welcoming speech by Mr. Alwin Schober, Secretary of State, Federal Ministry of Agriculture and Forestry, Vienna
  - Introductory address by Mr. L.R. Letourneau, Chief, Forest Logging and Transport Branch, Forestry Department, FAO
  - keynote speech by Mr. H. Hattinger, Forestry Department, Federal Ministry of Agriculture and Forestry, Vienna
  - Excursion to Ossiacher Tauern. Multiple functions of mountain forestry (A. Trzesniowski, R. Weiss)
  - Key address by Ir. F. Eggl, Director-General of the Austrian Federal Forestry Enterprise
  - Reception in the Rittersaal of the Stiftshotel, Ossiach
- Wednesday, 3 June**
- "Techniques in Wood Harvesting with a View to Increasing Wood Production and Saving Energy" (E. Pestal)
  - "Forest Research in Alpine Regions" (H. Egger)
  - "Application of Medium Technology in Wood Harvesting in Developing Countries" (R. Heinrich)
  - Demonstration of an agricultural tractor with Koller cable crane (K300) and small portable winches for ground skidding on Ossiacher Tauern (A. Trzesniowski and staff)
- Thursday, 4 June**
- "Requirements for Wheeled Tractors Used in Forest Work" (A. Trzesniowski)
  - Demonstration of agricultural tractors and auxiliary forestry equipment

Demonstration of Log Line (A. Trzesniowski and staff)

Friday, 5 June

Survey of a cable crane line (group work) (A. Trzesniowski and staff)

Design of setting-up plan for a cable crane from data surveyed (A. Trzesniowski and staff, R. Heinrich)

Saturday, 6 June

Continuation of design of setting-up plan for a cable crane from data surveyed (A. Trzesniowski and staff, R. Heinrich)

Excursion to Bad Kleinkirchheim

Visit of wooden houses of the Alpine Region

Trip by cable way to the Kaiserburg to study protection of nature, forestry and tourism (D. Hanak-Hammerl)

Sunday, 7 June

No official programme (Church visit and concert in Ossiach)

Monday, 8 June

Excursion to Klagenfurt

Visit of Minimundus Exhibition and Hochosterwitz castle (R. Heinrich, A. Trzesniowski)

Tuesday, 9 June

"Working Instructions for Cable Crane Installations in Austria" (A. Trzesniowski)

Demonstration of setting up, operation and dismantling of a URUS UNIMOG cable crane (staff of Forestry Training Centre)

Wednesday, 10 June

Excursion to Hespia-Tomäne, Wolfsberg

Logging demonstration by wheel skidder and mobile crane; visit to sawmill and timber yard (H. Clavadetscher, W. Brabeck, R. Heinrich, J. Hanak-Hammerl)

Thursday, 11 June

"Selection of Trees in Thinning Operations - Removal of Individual Trees in Secondary Forests" (G. Sonnleitner)

Review of forestry equipment produced by the Steyr Company (W. Strzygowski, G. Hacker)

Demonstration of Steyr forestry equipment on Ossiacher Tauern (G. Hacker, A. Trzesniowski, R. Heinrich)

Friday, 12 June

Continuation of demonstration of Steyr forestry equipment (G. Hacker)

Evaluation of the first part of the Course; drafting of conclusions and recommendations, final discussions and adoption of draft report (A. Trzesniowski, R. Heinrich)

**Saturday, 13 June**                      **Visit to Villach**  
**Farewell party at the Forestry Training Centre, Ossiach**

**Sunday, 14 June**                      **Transfer by bus from the Forestry Training Centre, Ossiach, to the Forestry Training Centre, Ort**  
**Itinerary: Ossiach - Bad Kleinkirchheim - Millstatt - Katschberg - Kuchl - Salzburg - Ort**  
**Arrival at Ort. Accommodation at the Forestry Training Centre**

**Monday, 15 June**                      **General information in the Lecture Hall of the Training Centre (R. Heinrich)**  
**Welcoming speech by Mr. H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry**  
**"Forest Road Construction between Economics and Protection of Nature" (E. Pestal)**  
**"Forestry and Ecology in Mountainous Areas" (E. Tüchy)**  
**Excursion to the federal forest district of Traunstein and to farmers' forests**  
**Demonstration of examples of forest road-nets in rocky and soft soil areas (O. Sedlak)**

**Tuesday, 16 June**                      **"Planning of Work Systems for Wood Harvesting in Mountainous Regions" (W. Egger)**  
**"General Principles on Planning of Forest Road-nets" (O. Sedlak)**  
**"Location and Costing of Forest Roads" (O. Sedlak)**  
**Practical planning and layout of forest roads; demonstration of surveying instruments (O. Sedlak)**

**Wednesday, 17 June**                      **Practical training; surveying and staking of the road alignment and additional necessary surveys for a forest road in steep terrain (O. Sedlak, R. Heinrich, and staff of the Forestry Training Centre)**

**Thursday, 18 June**                      **No official program (Church visit)**  
**Excursion to Salzburg; sightseeing tour; return trip via St. Gilgen - Wolfgangsee - Bad Ischl - Ort**

**Friday, 19 June**                      **Elaboration of the forest road project from the survey data by the participants (O. Sedlak)**  
**General introduction to forest road construction methods (O. Sedlak)**

**Saturday, 20 June**                      **Visit to Gmunden**  
**Excursion to Hallstatt (R. Heinrich, D. Hanak-Hammerl)**

**Sunday, 21 June**                      **No official programme**  
**(Church visit)**  
**Excursion to the Abbey of Kremsmünster**

**Monday, 22 June**                      **"Road Embankment Stabilization with Biological and Engineering Works for Forest Roads" (R. Heinrich)**  
**"Machine Input in Forest Road Construction with Special Emphasis on Rock Blasting in Mountainous Areas" (W. Blaha)**  
**"The Practical Application of Soil Testing Methods on Forest Roads" (J. Eisbacher)**  
**Demonstration of modern handtools for forestry with emphasis on ergonomic and economic aspects (E. Feichtinger)**

**Tuesday, 23 June**                      **"Work Organization in Wood Harvesting" (Staff of Training Centre)**  
**"Work Studies in Forestry" (Staff of Training Centre)**  
**Practical training in work studies in thinnings (J. Wenzl and staff)**

**Wednesday, 24 June**                      **"Torrent Control and Forest Roads" (H. Hattinger)**  
**"The Influence of Forest Roads on Run-off Development of Sedimentation and Landslides (H. Hattinger)**  
**Practical training in time studies (J. Wenzl and staff)**  
**"The Use of Telemetric and Computerized Ergonomic Measurements for Determining and Evaluating Physiological Parameters in Mechanized Wood Harvesting" (J. Wenzl)**

**Thursday, 25 June**                      **Elaboration of time studies and development of forest work programmes (F. Schwendt)**  
**"Work Systems and Costs in Wood Harvesting and their Influence on the Forest Worker and the Forest (F. Schwendt)**  
**"Mechanized Wood Harvesting and the Optimal Opening-up of Forests (F. Auböck)**

**Friday, 26 June**                      **Excursion to Gosau and Bad Goisern. Examples of a forest road under construction; protective constructions for forest roads and landslides; check dam under construction. Observation of wood harvesting systems with intermediate technology. (H. Hattinger, R. Heinrich, M. Jedlitschka, O. Sedlak)**

"Torrent Engineering Works for the Protection of Mountain Forest Roads in the Region "Salzkammergut", Austria (M. Jedlitschka)

Saturday, 27 June

Evaluation of the Course; drafting of conclusions and recommendations; final discussions and adoption of the draft report (R. Heinrich)

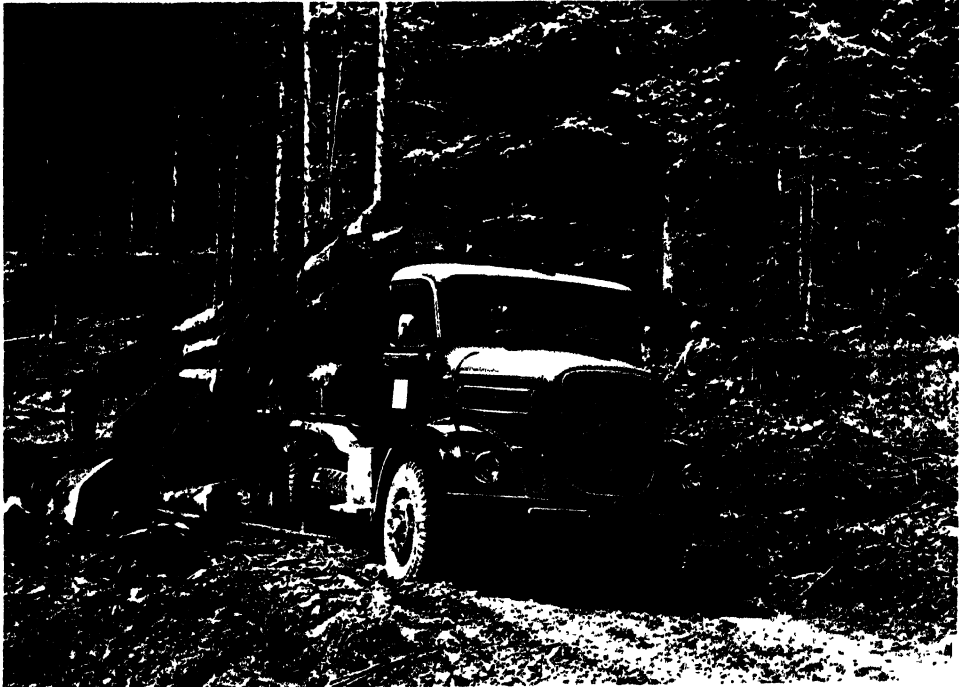
Farewell speeches:

- Dr. H. Redl, Head of the International Division, Federal Ministry of Agriculture and Forestry
- Mr. E. Plattner, Head of Forestry Department, Federal Ministry of Agriculture and Forestry

Farewell party at the Forestry Training Centre, Ort

Sunday, 28 June

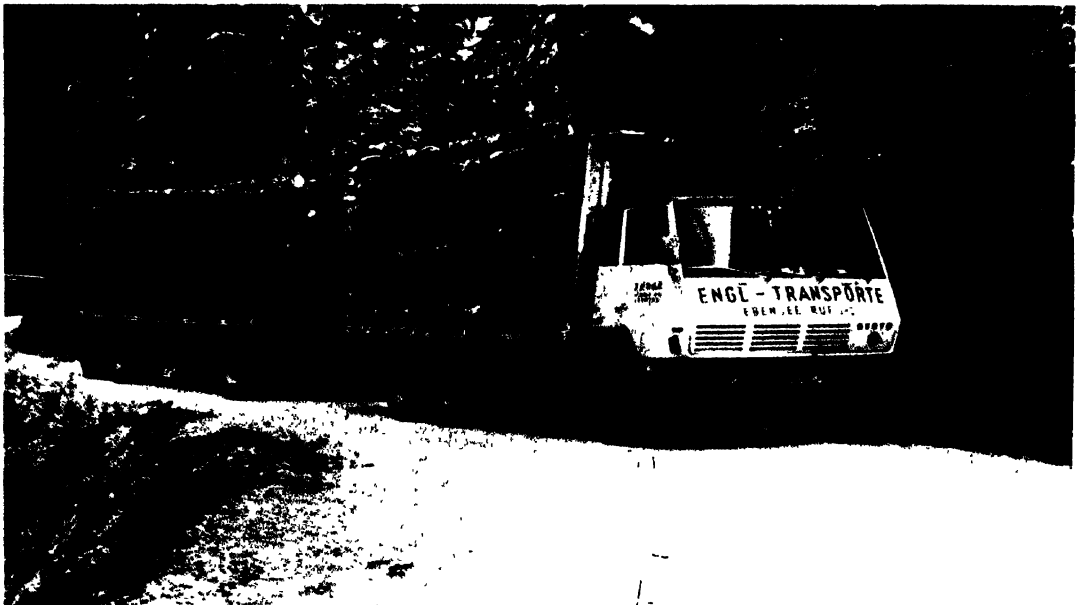
Return trip by bus from Ort to Vienna, Schwechat Airport



Logs loaded on to the truck by wire and built in loading winch (parbuckle)  
(Photo: E. Pestal)



Tree-length logs being transported by truck and trailer. Note the high road standard (curve and width) (Photo: E. Pestal)



Log transport by flatdeck truck with (pup) trailer on a narrow forest road in mountainous terrain (Photo: R. Heinrich)

ANNEX II

LIST OF COURSE PARTICIPANTS

<u>Country</u>	<u>Name</u>	<u>Address</u>
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	M.H. OBEID	Forests Administration P.O. Box 658 Khartoum
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Central timber yard for debarking, cross-cutting, sorting logs  
ready for further processing (Photo: R. Heinrich)



Wheeled grapple loader piling and transporting logs for a sawmill  
(Photo: R. Heinrich)

ANNEX III

LIST OF COURSE STAFF, LECTURERS AND SPEAKERS

(a) Austrian Organizing Committee

FRAUENHOLZ Othmar, Dipl.Ing. Direktor	Leiter der Forstlichen Ausbildungsstätte, Ort A-4815 Ort b. Gmunden
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(c) Course Directors

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